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SILICOFLAGELLATES FROM THE  
CRETACEOUS, EOCENE, AND MIOCENE  
OF CALIFORNIA, U.S.A.

By

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INTRODUCTION

This is a report of a stratigraphic analysis and a systematic catalogue of fossil silicoflagellates from nine localities in California. A detailed description of the stratigraphy of these localities has been reported earlier (Mandra, 1960). The fossil assemblages are Maastrichtian (Upper Cretaceous); Narizian (Upper Eocene); Relizian (Lower Miocene); Mohnian (Upper Miocene); and Delmontian ("Upper-most" Miocene or Mio-pliocene).

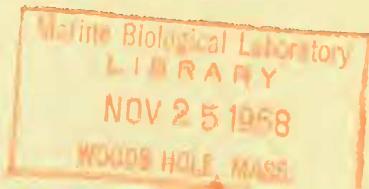
The species are illustrated by 83 figures, a *Literature Cited* section is included, a *Gazetteer* of world-wide silicoflagellate localities cited in this paper and a *Register of Localities* is presented.

Type material is deposited in the Stanford University Paleontological Type Collection.

It is a pleasure to acknowledge the help that Dr. G D. Hanna of the California Academy of Sciences has given me for many years. The Standard Oil Company of California and the California Academy of Sciences have contributed the complete publication costs of this paper.

STRATIGRAPHIC ANALYSIS

The stratigraphic investigation is sequential in nature. First it demonstrates, in the Slide Uniformity discussion, that mounted specimens on slides are random



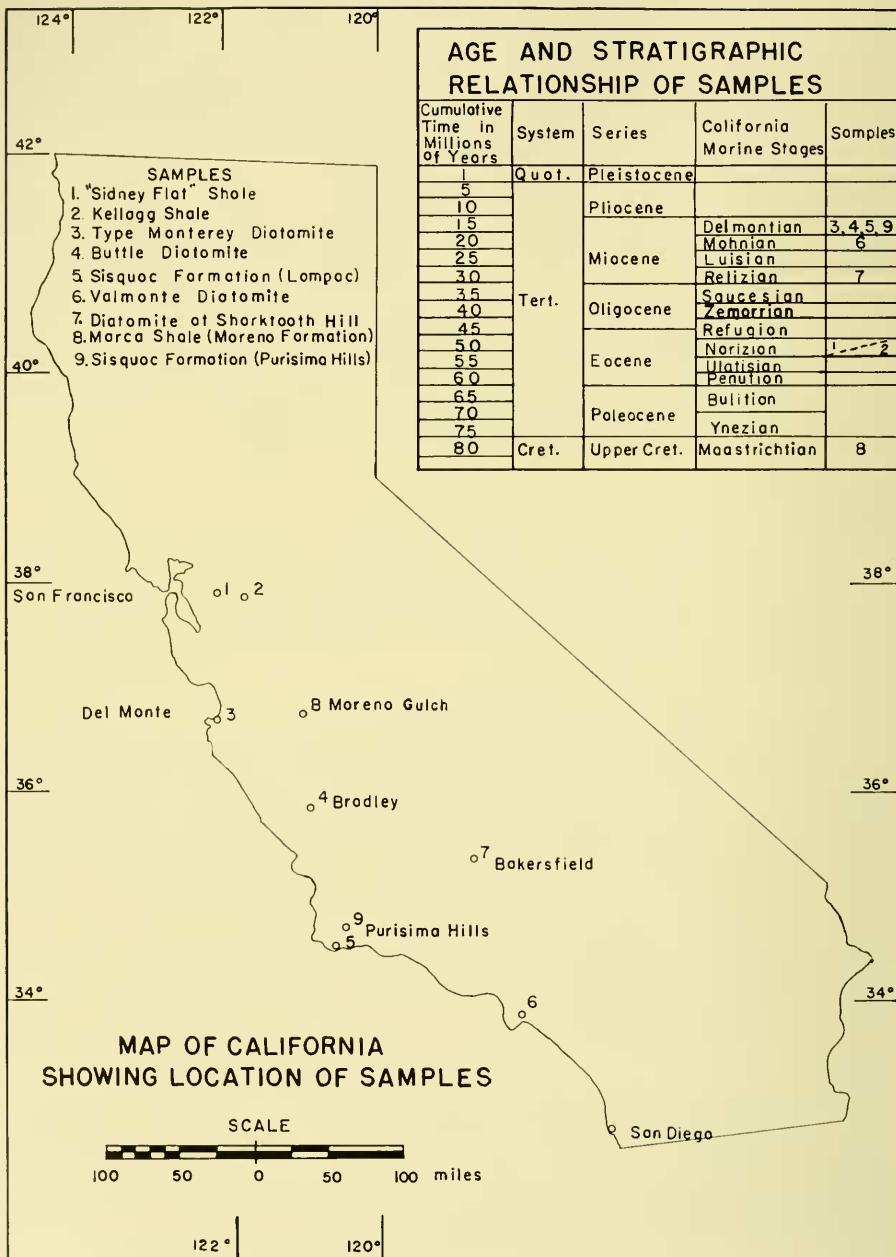


FIGURE 1. Map of California showing location, age and stratigraphic relationship of samples.

and representative. Then the Statistical Method is presented so that it can be used to demonstrate Horizon Uniformity and to analyze faunules from the different stages and series. Finally, tentative stratigraphic conclusions are reported.

#### SLIDE UNIFORMITY

Slide uniformity is defined here as statistical similarity of faunules, mounted on slides, from one horizon. Data in this section consist of detailed tabular evidence, which is interpreted and summarized as follows: there is no statistical difference between the faunules on slides from one horizon. Thus, the faunule on Sharktooth Hill Horizon A slide 1 is statistically the same as the faunules on slides 2, 3, and 4 of the same horizon. It is essential to demonstrate statistical uniformity of slides in order that mounted horizon assemblages can be considered random and representative. Without these two qualities all later statistical work in this report would be invalid.

Table 1 shows, in terms of relative abundance at each horizon, the occurrences of 34 species and varieties from the nine localities studied. The statistics for a horizon were obtained by random counts of 200 specimens ( $N = 200$ ) from a sample representing one horizon. Relative abundance of a species was determined on the basis of the number of times a species appeared in the random counts of 200 specimens. No more than 50 specimens were counted per slide; therefore, each horizon has a minimum of four slides. If, as is the case for Monterey Horizon B and Sharktooth Hill Horizon B, a slide does not contain 50 specimens, then the count is continued on a second slide. In the two horizons just mentioned, five slides were needed to complete the count of 200.

The recorded data of the Kellogg and "Sidney Flat" shales are exceptions to the procedure just described. Modifications were required because data from the two shales are not comparable to data from other localities; there are not enough silicoflagellates in the samples from the two Eocene shales. Therefore in order to make the data comparable, and useful, the following steps were taken:

1. Counts of Eocene slides were combined. For example, Kellogg shale slide 21 as reported in table 2 is, in reality, the summary of counts for slides 21, 21A, and 21C. The use of such combinations is a convenience by which data can be presented in nine (instead of 22) columns. The grouping of slides does not invalidate or weaken the statistics.

2. "Sidney Flat" shale counts are doubled in order for  $N$  to equal 200. For example, table 2 shows a count of eight for *Corbisema triacantha* on slide 5 of the "Sidney Flat" shale. In the Observed Frequencies Chart the count for the same species in the same shale is doubled and recorded as 16 for *Corbisema triacantha*. The doubling of counts weakens the "Sidney Flat" shale data in the sense that observed frequencies will not reveal their full potential. Thus, the faunule of sample X differs from the faunule of the "Sidney Flat" shale in that the "Sidney Flat" does not have species A and B, and sample X does. In this

TABLE 1. *Table of observed frequencies of California silicoflagellate species.*

CALIFORNIA SILICOFLAGELLATE SPECIES		SERIES	STAGE	FORMATION or MEMBER	HORIZON	* THE ARRANGEMENT OF THESE FOUR UNITS IS GEOGRAPHICALLY NORTH TO SOUTH, NOT GEOLGICALLY. DO NOT APPLY THE PRINCIPLE OF SUPERPOSITION TO THEIR POSITION IN THIS CHART.										
BY	YORK T. MANDRA					16432	1	17622	1	4	4940	3	—	—	—	—
Monterey	Calcareous	* MONTEREY FORMATION [Type Area]	B	2												
Butte	Siliceous	* BUTTE DIATOMITE	B	—												
Delmontian	Siliceous	* SISQUOC FORMATION (Purisima Hills)	B	—												
Miocene	Siliceous	* SISQUOC FORMATION (Lompoc Area)	B	3	53	3	2	4	18	11						6
	Siliceous		A	—	57	3	—	—	13	1	4					2
Mohnian	Siliceous	VALMONT DIATOMITE	B	—	—	—	—	—	—	—	—	—	—	—	—	2
	Siliceous		A	—	—	—	—	—	—	—	—	—	—	—	—	2
Relizian	Siliceous	DIATOMITE AT SHARK-TOOTH HILL	B	18	4	12	—	39	—	2	13	1				1
Eocene	Siliceous	* SIDNEY FLAT <sup>**</sup>	A	122	8	2	—	137	12	5						2
	Siliceous															2
Upper Eocene	Siliceous	KELLOGG SHALE	***	30	16	66	—	—	24							28
	Siliceous															28
Cretaceous	Siliceous	MAAS-TRICHTIAN	MAAS-MORENO FORMATION	A	68	13	32	—	12	14						39
	Siliceous															39
																13

\* THE ARRANGEMENT OF THESE FOUR UNITS IS GEOGRAPHICALLY NORTH TO SOUTH, NOT GEOLGICALLY. DO NOT APPLY THE PRINCIPLE OF SUPERPOSITION TO THEIR POSITION IN THIS CHART.

\*\* SIDNEY FLAT SHALE DATA HAVE BEEN ADJUSTED TO MAKE THEM COMPARABLE TO DATA FROM OTHER LOCALITIES.

\*\*\* FIVE KELLOGG SHALE SAMPLES ARE GROUPED TOGETHER AND TREATED AS ONE SAMPLE.

TABLE 2. *Slide and horizon counts*

Monterey formation (type area)	Slide number	Horizon A				Horizon B				
		1	2	3	4	9	10	11	12	13
<i>Cannopilus binocularis</i>		0	0	1	0	0	2	0	0	0
<i>Distephanus ornamentosus</i>	42	46	46	42		22	39	24	42	37
<i>Distephanus speculum</i>	8	4	3	7		5	9	7	8	3
<i>D. speculum brevispinus</i>	0	0	0	1		0	0	0	0	1
<i>Mesocena crenulata elliptica</i>	0	0	0	0		0	0	1	0	0
<b>Butte diatomite</b>										
Slide number	1	2	3	4		9	10	11	12	
<i>Cannopilus binocularis</i>	0	1	0	0		0	1	0	0	
<i>Cannopilus calyptra</i>	1	1	1	1		1	0	0	0	
<i>Corbisema</i> species	0	0	1	0		0	0	0	0	
<i>Dictyocha fibula</i>	0	1	0	0		0	0	0	0	
<i>Distephanus crux</i>	0	1	1	0		0	1	0	3	
<i>Distephanus ornamentosus</i>	3	0	0	0		0	0	0	0	
<i>Distephanus speculum</i>	39	41	41	41		37	39	39	34	
<i>D. speculum brevispinus</i>	6	4	4	6		11	8	10	11	
<i>D. speculum pentagonus</i>	0	1	1	1		1	0	1	1	
<i>Mesocena crenulata diodon</i>	0	0	0	1		0	0	0	0	
<i>Mesocena hexagona</i>	0	0	0	0		0	1	0	0	
<i>Paradictyocha polyactis</i>	1	0	1	0		0	0	0	1	
<b>Sisquoc formation (Purisima Hills)</b>										
Slide number	1	2	3	4		5	6	7	8	
<i>Cannopilus binocularis</i>	0	0	0	1		0	0	0	0	
<i>Dictyocha fibula</i>	1	0	0	0		3	1	0	0	
<i>Distephanus crux</i>	1	0	0	1		1	0	2	6	
<i>Distephanus speculum</i>	46	50	48	46		46	47	46	44	
<i>D. speculum brevispinus</i>	2	0	1	1		0	2	1	0	
<i>Paradictyocha polyactis</i>	0	0	1	1		0	0	1	0	
<b>Sisquoc formation (Lompoc)</b>										
Slide number	6	7	8	9		1	2	3	4	
<i>Cannopilus binocularis</i>	0	1	0	0		0	2	1	0	
<i>Dictyocha fibula</i>	14	18	12	13		15	12	10	16	
<i>Dictyocha fibula rhombica</i>	1	1	1	0		1	1	1	0	
<i>Dictyocha staurodon</i>	1	0	0	0		1	0	0	1	
<i>Distephanus crux</i>	0	0	1	0		1	1	1	1	
<i>Distephanus speculum</i>	32	29	36	34		26	29	34	29	
<i>D. speculum brevispinus</i>	1	0	0	3		3	3	3	2	
<i>Paradictyocha polyactis</i>	1	1	0	0		3	2	0	1	
<b>Valmonte diatomite</b>										
Slide number	1	2	3	4		9	10	11	12	
<i>Cannopilus binocularis</i>	0	0	1	0		1	0	0	0	
<i>Cannopilus cyrtoides</i>	0	0	1	0		0	0	0	0	
<i>Cannopilus hemisphericus</i>	0	1	0	0		1	0	0	0	
<i>Cannopilus sphericus</i>	5	3	3	7		0	3	5	3	
<i>Dictyocha fibula</i>	0	0	1	0		0	0	1	0	
<i>Dictyocha fibula stapedia</i>	1	0	0	0		0	0	0	0	
<i>Distephanus crux</i>	3	2	2	0		2	0	2	0	
<i>Distephanus speculum</i>	1	1	1	1		2	1	3	0	

TABLE 2. (Continued)

Valmonte diatomite (continued)	Horizon A				Horizon B				
	Slide number	1	2	3	4	9	10	11	12
<i>D. speculum brevispinus</i>		1	0	1	0	0	0	0	0
<i>Mesocena crenulata</i>		3	3	0	0	0	0	0	0
<i>Mesocena crenulata diodon</i>		32	35	38	39	37	40	36	44
<i>Mesocena crenulata elliptica</i>		0	0	0	0	0	1	0	1
<i>Mesocena polymorpha</i>		0	2	0	1	0	0	0	0
<i>Mesocena polymorpha triangula</i>		3	2	2	1	5	3	0	1
<i>Paradictyocha polyactus</i>		1	1	0	1	2	2	3	1
Diatomite at Sharktooth Hill									
Slide number	1	2	3	4	9	10	11	12	13
<i>Cannopilus binoculus</i>	0	1	0	0	0	0	0	0	0
<i>Cannopilus calyptra</i>	5	5	6	6	0	6	8	4	0
<i>Cannopilus cyrtoides</i>	0	0	0	0	0	1	1	2	0
<i>Cannopilus hemisphericus</i>	5	1	1	1	4	4	2	2	0
<i>Cannopilus sphericus</i>	2	0	0	0	0	0	0	0	0
<i>Dictyocha ausonia</i>	0	0	0	1	0	0	0	0	0
<i>Dictyocha fibula</i>	30	33	35	39	18	32	33	36	20
<i>Distephanus crux</i>	5	1	5	1	1	5	3	3	0
<i>Distephanus speculum</i>	3	7	3	2	3	1	3	3	3
<i>D. speculum brevispinus</i>	0	0	0	0	0	1	0	0	0
<i>Mesocena polymorpha triangula</i>	0	2	0	0	1	0	0	0	0
Eocene samples									
Slide number	Kellog shale				"Sidney Flat" shale				
	17	19	21	22	5	7	11	12	14
<i>Corbisema apiculata</i>	13	23	21	11	2	7	1	3	2
<i>Corbisema triacantha</i>	1	1	3	8	8	0	0	0	0
<i>Dictyocha fibula</i>	8	7	7	10	3	6	10	11	3
<i>Distephanus speculum</i>	0	6	4	2	0	0	0	0	0
<i>Distephanus variabilis</i>	1	0	9	4	4	5	3	0	0
<i>Mesocena oamaruensis</i>	0	0	10	0	0	0	0	0	0
<i>Mesocena occidentalis</i>	0	0	1	2	2	6	6	2	1
<i>M. polymorpha biseptenaria</i>	0	0	6	0	0	0	0	0	0
<i>M. polymorpha quadrangula</i>	0	0	0	3	0	1	0	1	0
<i>Naviculopsis biapiculata</i>	11	10	12	6	0	7	1	2	4
Cretaceous samples									
Slide number	Marca shale								
	1	2	3	4					
<i>Corbisema geometrica</i>	10	9	4	2					
<i>Lyramula furcula</i>	36	35	42	45					
<i>Lyramula simplex</i>	0	2	0	2					
<i>Vallacerta hortoni</i>	4	4	4	1					

case it is possible, mathematically, to assume that if the "Sidney Flat" shale contained 200 specimens (instead of 100) then species A and B might have been present.

Recorded counts of table 2 are uniform in the sense that all slides from one horizon have the same species as the most abundant species. Hence the distribution of species on slides is random and representative. *Distephanus ornamentus*,

being the most abundant species on each of the nine slides from the Monterey formation (type area) Horizon A and Horizon B, occupies rank-order position no. 1. The following species, each in its own area, likewise occupy rank-order position no. 1: *Distephanus speculum* on all 16 slides of Sisquoc formation and all eight slides of the Buttle diatomite; *Mesocena crenulata diodon* on all eight slides of Valmonte diatomite; *Dictyocha fibula* on all nine slides of diatomite at Sharktooth Hill; *Corbisema apiculata* on all four slides of Kellogg shale; *Lyramula furcula* on all four slides of Marca shale.

The conclusion, based on the above data, that all slides from one horizon are uniform, random, and representative is supported by additional evidence. In two-thirds of the horizons studied the second most abundant species, on each slide, is the same species for all slides from one horizon. Thus, *Distephanus speculum* occupies rank-order position no. 2 on each of the nine slides from Monterey formation (type area) Horizon A and Horizon B. The following species, again each in its own area, have the same rank-order position (no. 2): *Distephanus speculum brevispinus* on all eight slides of Buttle diatomite; *Distephanus speculum brevispinus* on all four slides of Sisquoc (Purisima) Horizon A; *Dictyocha fibula* on all eight slides of Sisquoc (Lompoc); *Cannopilus sphericus* on all four slides of Valmonte diatomite Horizon A; *Naviculopsis bia piculata* on all four slides of Kellogg shale; *Corbisema geometrica* on all four slides of Marca shale.

In the remaining one-third of the horizons the number of specimens is so small as to have only limited statistical value. Nevertheless in the total random count of 400 specimens from the Sisquoc formation (Purisima) Horizon B and Valmonte diatomite Horizon B, the rank-order for slides from one horizon is so close that a change in count of only nine specimens would result in agreement of abundance (rank-order positions 1 and 2) in each of the two horizons. Similar agreement could be obtained by a change in count of only six specimens in the Sharktooth Hill horizons. From these data the conclusion is drawn that the mounted specimens are mathematically not biased, and therefore can be used in a statistical analysis.

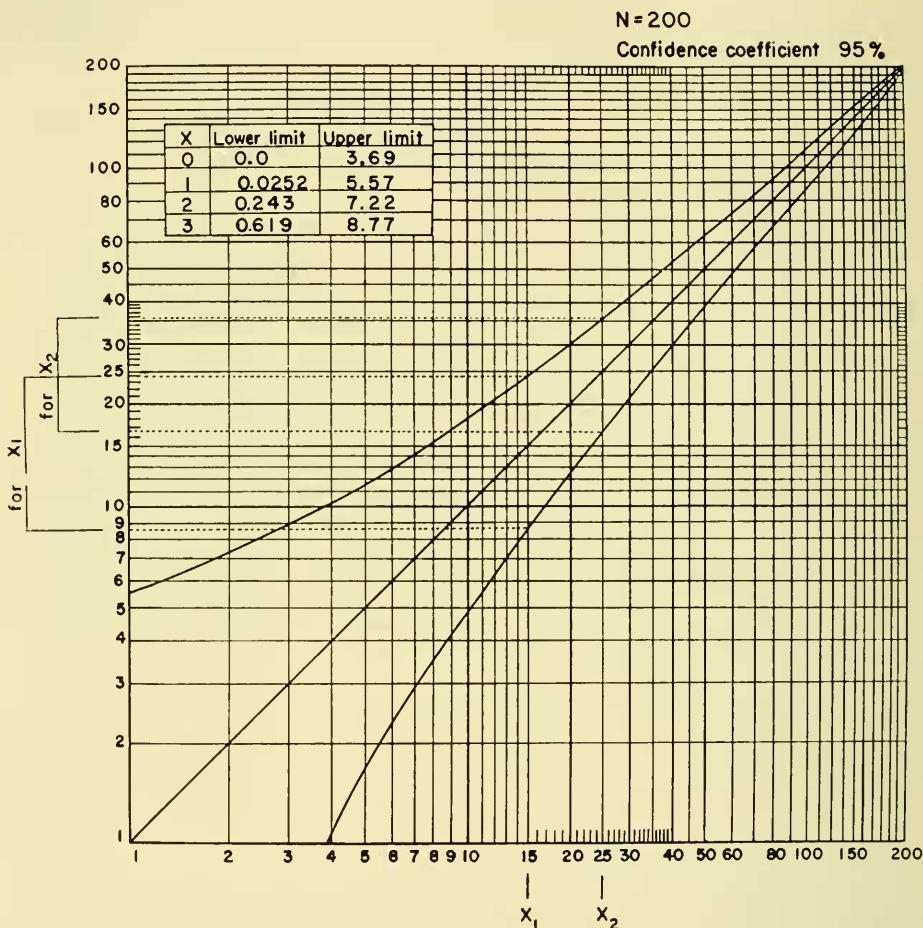
#### STATISTICAL METHOD

A brief explanation of the statistical methodology used is presented here. It is a consequence of the theory of probability (Binomial Distribution) that if a population has a specified proportion of members with a given attribute, then samples drawn at random from the population will contain members with this attribute in approximately the same proportion.

EXAMPLE A. If a box contains 100,000,000 marbles (thoroughly mixed), 10,000,000 of which are black, then random large samples drawn from this box will, in general, contain about  $\frac{1}{10}$  black marbles.

Furthermore, probability statements concerning the number of objects with the required attributes in a sample of known size can be made.

TABLE 3.  
LIMITS OF EXPECTATION CORRESPONDING TO  
OBSERVED FREQUENCY



EXAMPLE B. In a series of independent random samples, each of size 200 and a population of marbles  $\frac{1}{5}$  of whose members are black, one would expect that 95 percent of the time the number of black marbles would lie between 16.5 and 31. The lower limit of the expected frequency is 16.5, and the upper limit is 36. The coefficient of confidence is 95 percent.

The graph (table 3) was drafted by Taro Kanaya (1957, p. 61) from table VIII of Fisher and Yates (1949, p. 48). It is used in the following manner:

1. If a sample of  $N = 200$  ( $N = 200$  is used throughout this report) has an observed frequency of 25 (=  $X_2$ ) then the population proportion is estimated to be  $\frac{25}{200}$  or  $\frac{1}{8}$  and the upper limits of expected frequency is computed to be 36. On table 3 see dashed line striking intersection of 25 ordinate and lower curved line. The lower limit is 16.5.

2. Similarly, if the observed frequency is 15 (=  $X_1$ ), then the upper and lower limits are 24.2 and 8.5 respectively.

3. Since in Examples 1 and 2 the lower and upper limits of  $X_1$  and  $X_2$  overlap in the area 16.5 to 24.2, it is concluded here that at the 95 percent confidence coefficient level the frequency is the same. All data in this report are computed at the 95 percent confidence coefficient level. On the basis of statistics, therefore, the predictions made here are expected to be correct 95 percent of the time.

4. If the lower and upper limits do not overlap, as in the case for 10 (with lower limit of 5 and upper limit of 18) and 50 (lower limit 40, upper limit 63), then it is concluded that at the 95 percent confidence coefficient level the frequencies are different and that the difference is real and has significance.

5. The data on table 3 also show that if a particular species does not occur ( $X = 0$ ), then its lower limit is zero and its upper limit 4 (3.69 rounded off to the nearest whole number). It also shows that the lower limits of a species with a frequency of nine is 4 and its upper limit is 17. These two ranges overlap at 4. Therefore they are not statistically different. From this statistical relationship it follows that the absence of a species has no significance unless it is compared to a frequency greater than nine.

For example the absence of *Cannopilus cyrtoides* in Sharktooth Hill A and its presence in Horizon B with a frequency of four has no significance. The limits of zero are 4 for the upper limit and zero for the lower limit; the limits of four are 10 for the upper limit and 1 for the lower limit. The two intervals overlap in the range 1-4. To have significance Horizon B should have *Cannopilus cyrtoides* wth an observed frequency of 10. Then the limits (0-4 and 5-18) would not have overlapped.

#### HORIZON UNIFORMITY

Horizon uniformity is defined here as the statistical similarity of faunules from different horizons of one locality. In other words, 95 percent of the time the predetermined limits of variation in the faunule of one horizon will not be exceeded by the limits of variations in the faunules from other horizons of the same locality.

Data in this section consists of statistical inferences based upon facts obtained from the table on upper and lower limits. The conclusion is summarized as follows: There is no statistical difference, at the 95 percent confidence coefficient, between horizons at each locality. Thus, the faunule of the Monterey formation (type area) Horizon A is statistically the same as the faunule of

TABLE 4. *Limits of expectation corresponding to observed frequency used in this Report.<sup>1</sup>*  
*(Confidence coefficient 95 percent and N = 200)*

Observed frequency	Upper limit	Lower limit									
0	4	0	18	28	11	39	52	29	118	130	105
1	6	0	19	29	12	40	54	30	130	143	115
2	7	0	20	30	12	42	54	31	131	145	115
3	9	1	21	31	13	47	59	36	137	150	120
4	10	1	22	32	14	50	63	38	139	155	125
5	12	2	23	33	15	52	64	40	144	155	130
6	13	2	24	35	16	53	65	40	145	157	130
7	14	3	25	36	16	56	68	43	149	160	135
8	16	3	26	37	17	57	70	45	157	165	140
9	17	4	27	38	18	58	70	46	158	166	142
10	18	5	28	39	19	66	77	53	162	170	150
11	20	6	29	41	20	68	79	55	164	170	150
12	22	6	30	42	21	74	86	60	176	185	165
13	23	7	31	43	22	75	88	61	183	190	173
14	23	8	32	44	23	77	90	64	190	195	180
15	24	9	33	45	24	95	108	81			
16	25	9	34	46	24	102	113	87			
17	26	10	37	49	27	117	130	103			

<sup>1</sup> Data interpolated from table VIII of Fisher and Yates (1949, p. 48), and from table 3 of this report, and rounded off to the nearest whole number.

Horizon B. Similar relationships exist for horizons at Buttle Canyon, both of the Sisquoc formation localities, Peck Park, and Sharktooth Hill. Hence the two horizons from each locality are treated as one horizon.

Upper and lower limits at the 95 percent confidence level are plotted on table 5; therefore in order to compare two horizons, one has to compare the same species in both horizons. If their intervals (upper and lower limits) are mutually exclusive, then one concludes that there exists a valid statistical difference between species A population of one horizon and species A population of the other horizon. If the intervals of species A overlap, then one may draw the warranted conclusion that the populations of that species are not different. Furthermore if the intervals of all species tested overlap, then the horizons would be considered the same.

Example 1. The faunules of Horizons A and B of Monterey formation (type area) are the same. *Cannopilus binoculus* intervals are 0-7 and 0-6 (table 5). They overlap in the 0-6 range; hence they are considered to be the same at the 95 percent confidence coefficient level. Similarly: *Distephanus ornamentosus*, 150-170 and 165-185, overlap in the range 165-170; *Distephanus speculum*, 23-45 and 14-32, overlap in the range 23-32; *Distephanus speculum* var. *brevispinus*, 0-6 and 0-6, overlap in the 0-6; *Mesocena crenulata* var. *diodon*, 0-6 and 0-4, overlap in the range 0-4.

TABLE 5. *Upper and lower limits of observed frequencies.<sup>2</sup>*

SERIES	STAGE	FORMATION or MEMBER	HORIZON	SILICOFLAGELLATE SPECIES												
		* MONTEREY FORMATION (Type Area)	B	1023.0	1024.6	1025.6	1026.0	1027.0	1028.0	1029.0	1030.0	1031.0	1032.0	1033.0	1034.0	
			A	0	165.14	165.16	165.18	165.20	165.22	165.24	165.26	165.28	165.30	165.32	165.34	165.36
		* BUTTE DIATOMITE	B	0	4	10.4	16.54	1	0	0	0	0	0	0	0	0
			A	0	0	0	1.50	2	1	0	0	0	0	0	0	0
		DELMONTON*	A	6.10	6	7	9.70	30	9	4	0	0	0	0	0	0
MIOCENE	SISILOC FORMATION (Purisima Hills)	B	0	1	4	173	1	0	17	190	9	0	0	0	0	0
		A	0	0	0	0	0	0	0	180	1	0	0	0	0	0
	* SISILOC FORMATION (Lompoc Area)	B	6	6	0	1	0	106.6	106.7	106.8	106.9	107.0	107.1	107.2	107.3	107.4
		A	0	40.1	0	1	0	106.6	106.7	106.8	106.9	107.0	107.1	107.2	107.3	107.4
MIocene	MOHIAN DIATOMITE	B	9	45.9	7	10	10.0	130.20	130.21	130.22	130.23	130.24	130.25	130.26	130.27	130.28
		A	0	45.1	0	1	0	106.7	106.8	106.9	107.0	107.1	107.2	107.3	107.4	107.5
	DIATOMITE AT SHARK-	B	0	11.1	6.0	0	125	6	7	0	0	0	0	0	0	0
	TOTH HILL	A	6	11.1	0.2	4	0	125	2	2	2	2	2	2	2	2
EOCENE	UPPER EOCENE KELLOGG SHALE	**	6.32	4	16.7	6.150	2	2	24.4	24.5	24.6	24.7	24.8	24.9	24.10	24.11
		***	4.2	2.5	77	4	0	16	3.5	4	4	4	4	4	4	4
			5.5	7	23	6	0	16	8	5	5	5	5	5	5	5
CRETA-COUS	MAAS-TRICHTAN	MORENO FORMATION MARCA SHALE	A	16	79	23	44	22	22	2.5	1.9	1.9	1.9	1.9	1.9	1.9
				36	36	36	36	36	36	36	36	36	36	36	36	36

\* THE ARRANGEMENT OF THESE FOUR UNITS IS GEOGRAPHICALLY NORTH TO SOUTH, NOT GEOLOGICALLY. DO NOT APPLY THE PRINCIPLE OF SUPERPOSITION TO THEIR POSITION IN THIS CHART.

"SIDNEY FLAT" SHALE DATA HAVE BEEN ADJUSTED TO MAKE THEM COMPARABLE TO DATA FROM OTHER LOCALITIES.

\*\*\*\* FIVE KELLOGG SHALE SAMPLES ARE GROUPED TOGETHER AND TREATED AS ONE SAMPLE.

TABLE OF UPPER AND LOWER LIMITS OF OBSERVED FREQUENCIES

BY  
YORK T. MANDRA

VOL. XXXVI] MANDRA: CALIFORNIA FOSSIL SILICOFLAGELLATES

TABLE OF UPPER AND LOWER LIMITS OF OBSERVED FREQUENCIES

BY  
YORK T. MANDRA

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1918 1920 1922  
1924 1926 1928  
1930 1932 1934  
1936 1938 1940  
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Example 2. The faunules of the "Sidney Flat" shale and Kellogg shale are not the same. *Corbisema apiculata* intervals are 21–42 and 55–79 (table 5). These intervals do not overlap. Hence they are considered to be different at the 95 percent confidence coefficient level. Similarly: *Dictyoche fibula*, intervals 53–77 and 23–44, do not overlap; *Distephanus speculum*, intervals 0–4 and 6–22, do not overlap; *Mesocena oamaruensis*, intervals 0–4 and 5–18, do not overlap. The remaining species, common to both shales, have overlapping intervals. On this evidence the "Sidney Flat" shale faunule is considered to be different from the faunule of the Kellogg shale.

With reference to Example 2, two items should be pointed out:

1. The Kellogg shale and "Sidney Flat" shale are not horizons of one formation (as the Buttle diatomite Horizon A and Horizon B). They are two lithologic units from two localities.

2. The doubling of counts described earlier influences the "Sidney Flat" data. Since the "Sidney Flat" shale had an original count of 100 (instead of 200) it is possible to assume that in a  $N = 200$  sample more *Distephanus speculum*, *Corbisema apiculata*, and *Mesocena oamaruensis* would have been present. If the "Sidney Flat" had one more *Mesocena oamaruensis*, 13 more *Corbisema apiculata*, and one more *Distephanus speculum*, then these species populations would be considered similar in both shales (instead of different). However the frequencies of the remaining species, *Dictyoche fibula*, *Mesocena oamaruensis*, and *Naviculopsis biapiculata* constitute strong evidence which indicates that the two faunules differ. The evidence of the latter three species is not weakened by the faunal incompleteness of the "Sidney Flat" shale. The "Sidney Flat" shale has more specimens of these three species than the Kellogg. Hence their intervals do not overlap, and if more specimens are assumed for the "Sidney Flat" shale, existing differences between the two faunules cannot disappear.

#### STRATIGRAPHIC CONCLUSIONS

A detailed discussion of the stratigraphic aspects of these localities at the stage level is in a prior work (Mandra, 1960). Here, only the conclusions are presented.

Conclusions 2 to 7 have reference to Teilzones and Teilchrons of California species and genera, not biozones.

1. Silicoflagellates at the generic and specific level have value as another correlation tool.
2. Two statistically valid genera (*Vallacerta* and *Lyramula*), and three species (*Corbisema geometrica*, *Lyramula furcula*, and *Vallacerta hortoni*) seem to be restricted to the Upper Cretaceous.
3. One statistically valid genus, (*Naviculopsis*), and five species in other genera (*Corbisema apiculata*, *Corbisema triacantha*, *Distephanus variabilis*,

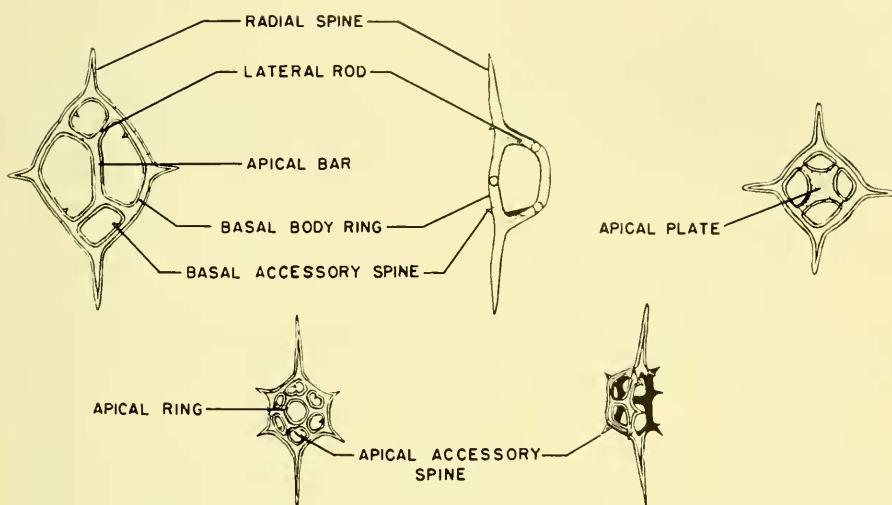


FIGURE 2. Nomenclature of the silicoflagellate skeleton. (After Tynan and Deflandre.)

*Mesocena oamaruensis*, and *Mesocena occidentalis*) appear to be Upper Eocene markers.

4. Six statistically valid species (*Cannopilus calyptra*, *Cannopilus hemisphericus*, *Cannopilus sphericus*, *Distephanus crux*, *Distephanus speculum* var. *brevispinus*, *Mesocena crenulata* var. *diodon*) appear to be confined to two or more California Miocene Stages.

5. The joint occurrences of *Mesocena crenulata* var. *diodon* and *Cannopilus sphericus* indicate Mohnian Age.

6. *Distephanus ornamentatus* is restricted to the Delmontian Stage.

7. Hanna (1931, pp. 198–201) and this study confirm the presence of *Mesocena* in Eocene strata. Hence the restriction of *Mesocena* to the Miocene as reported by Tynan (1957, pp. 133, 134) must be modified.

#### SYSTEMATIC CATALOGUE

The synonymy is arranged alphabetically by genera and species.

Quotation marks around a geographic name indicate that the fossil locality has not been accurately reported by prior workers.

Age designations in this section are those of Zanon (1934). They are used with a general rather than a precise connotation. The following areas either are not dated by Zanon or are dated more accurately by the authors cited: Barbados, island north of South America, late Eocene-older Oligocene (Kanaya, 1957); Karand, Hungary, late Tertiary (Gemeinhardt, 1931); Monterey formation in California, United States, Miocene (Kleinpell, 1937); Moreno formation in California, United States, Upper Cretaceous (Hanna, 1928); Oamaru, New

Zealand, late Eocene (Kanaya, 1957); "Senonien de la craie de Prusse," Germany, Upper Cretaceous (Deflandre, 1950).

Abundance is recorded under Occurrences in Samples Studied in the following manner: Diatomite at Sharktooth Hill (1 percent). The number in parentheses indicates that in the area studied, the species constitutes approximately 1 percent of the silicoflagellate faunule found in the diatomite.

Phylum PROTOZOA

Class MASTIGOPHORA

Order SILICOFLAGELLATA Borgert, 1891

Family DICTYOCHEIDAE Lemmermann, 1901

[nom. correct. Deflandre, 1950, p. 47 (pro family Dictyochaceae Lemmermann, 1901, p. 255)]

Genus **Cannopilus** Haeckel

*Cannopilus* HAECKEL, 1887, p. 1567. Type species (by subsequent designation, Frenguelli, 1940, p. 69): *Cannopilus hemisphericus* (Ehrenberg) = *Dictyochea hemisphericus* EHRENBURG, 1844.

Range of genus in California to date: Miocene.

World-wide range of genus: Miocene-Recent.

Distribution of genus: Cosmopolitan.

**Cannopilus binoculus** (Ehrenberg).

(Figures 68, 73, 77, 82.)

*Dictyochea binoculus* EHRENBURG, 1844, p. 79. EHRENBURG, 1854, pl. 19, fig. 42.

*Cannopilus binoculus* (EHRENBURG). LEMMERMANN, 1901, p. 266, pl. 11, fig. 22. SCHULZ, 1928, pp. 264-265, figs. 60a, 60b, 60c. GEMEINHARDT, 1930, p. 73, fig. 61. ZANON, 1934, p. 35, figs. 49-52.

TYPE LOCALITY. Not stated in original publication.

DIAGNOSTIC FEATURES. Skeleton consists of a six-sided basal ring, with six radial spines; six internal bars rising from basal ring support two apical windows.

DIMENSIONS. With spines: maximum, 60  $\mu$ ; average, 48  $\mu$ . Spines, 5-10  $\mu$ .

STRATIGRAPHIC RECORD. Lower Neogene (Moron, Spain): middle Neogene (Marzullo, Italy; "Santa Monica," United States; Szakal, Hungary): upper Miocene (Catanzaro and Gabbro, Italy); upper Neogene (Aegina, island near Greece; Mondaino, Italy).

OCCURRENCES IN SAMPLES STUDIED. Diatomite at Sharktooth Hill (less than 1 percent), Valmonte diatomite (less than 1 percent), Buttle diatomite (less than 1 percent), lower part of Sisquoc formation of Lompoc area (1 percent), lower part of Sisquoc formation of Purisima Hills (less than 1 percent), Monterey formation at type area (less than 1 percent).

**Cannopilus calyptra** Haeckel.

(Figure 80.)

*Cannopilus calyptra* HAECKEL, 1887, p. 1568. LEMMERMANN, 1901, p. 267. SHULZ, 1928,

p. 266, figs. 62a, 62b, 62c, 62d, 62e. GEMEINHARDT, 1930, p. 75, fig. 62. ZANON, 1934, p. 36, fig. 54.

**TYPE LOCALITY.** Greece and Sicily are cited in original publication.

**DIAGNOSTIC FEATURES.** Skeleton consisting of a six-sided basal ring, with six radial spines; four to seven irregular apical windows supported by six or seven unequal internal bars.

**DIMENSIONS.** With spines: maximum, 40  $\mu$ ; average, 35  $\mu$ . Spines, 3–8  $\mu$ .

**STRATIGRAPHIC RECORD.** Middle Miocene (Montaiate and Pesaro, Italy); middle Neogene ("Monterey," "Redondo," and "Santa Monica," United States; Nyermegy, Hungary).

**OCCURRENCES IN SAMPLES STUDIED.** Diatomite at Sharktooth Hill (10 percent), Buttle diatomite (1 percent).

### **Cannopilus cyrtoides Haeckel.**

(Figures 58, 75.)

*Cannopilus cyrtoides* HAECKEL, 1887, p. 1569, pl. 114, figs. 11, 12. LEMMERMANN, 1901, p. 268. SCHULZ, 1928, pp. 268–269, figs. 65a, 65b, 65c, 65d, 65e. GEMEINHARDT, 1930, p. 77, fig. 64. ZANON, 1934, p. 36.

**TYPE LOCALITY.** "Pacific."

**DIAGNOSTIC FEATURES.** Skeleton consisting of a basal septagonal or octagonal ring with seven to eight radiating spines, two of which usually are longer than the others; three to ten apical windows supported by seven or eight unequal internal bars.

**DIMENSIONS.** With spines: maximum, 40  $\mu$ ; average, 32  $\mu$ . Spines, 3–5  $\mu$ .

**STRATIGRAPHIC RECORD.** Middle Neogene ("Redondo" and "Santa Monica," United States; Szt. Peter, Hungary); undifferentiated Tertiary (Serralunga di Crea, Italy).

**OCCURRENCES IN SAMPLES STUDIED.** Valmonte diatomite (less than 1 percent), diatomite at Sharktooth Hill (1 percent).

### **Cannopilus hemisphericus (Ehrenberg).**

(Figures 60, 63, 66, 71.)

*Dictyocha hemisphericus* EHRENBURG, 1844, p. 266.

*Cannopilus hemisphericus* (Ehrenberg). HAECKEL, 1887, p. 1569. LEMMERMANN, 1901, p. 268, pl. 11, fig. 21. LEMMERMANN, 1903, p. 32, fig. 107. SCHULZ, 1928, p. 268, figs. 64a, 64b. GEMEINHARDT, 1930, p. 76, fig. 63.

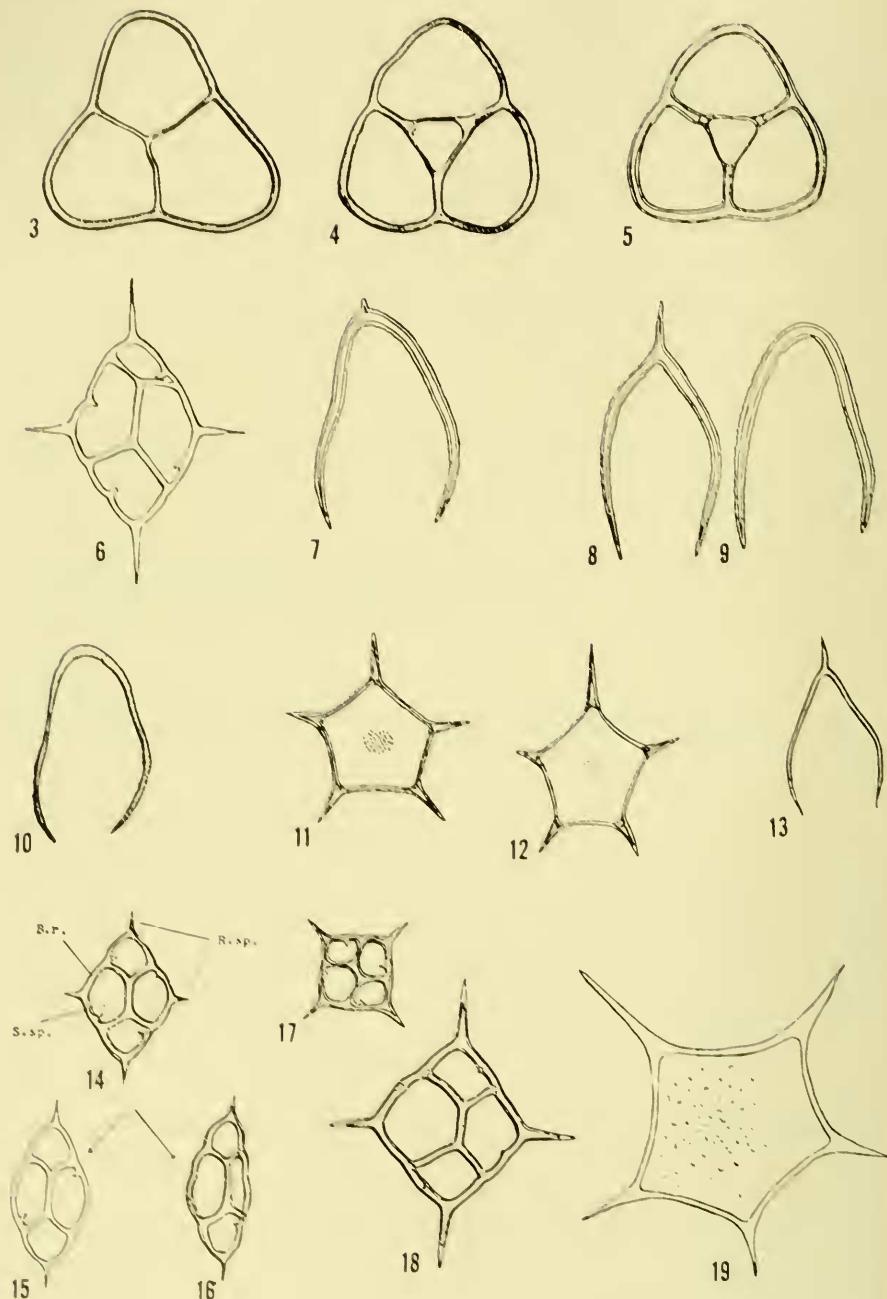
**TYPE LOCALITY.** "North Atlantic" and Bermuda are cited in original publication.

**DIAGNOSTIC FEATURES.** Skeleton is nearly hemispherical, with six centripetal teeth.

**DIMENSIONS.** With spines: maximum 50  $\mu$ ; average, 40  $\mu$ . Spines, 3–8  $\mu$ .

**STRATIGRAPHIC RECORD.** Middle Neogene (Bremia, Nagy Kurtos, and Szt. Peter, Hungary).

**OCCURRENCES IN SAMPLES STUDIED.** Diatomite at Sharktooth Hill (5 percent), Valmonte diatomite (less than 1 percent).



**Cannopilus sphericus** Gemeinhardt.

(Figure 70.)

*Cannopilus sphericus* GEMEINHARDT, 1931, p. 105, pl. 10, fig. 4. FRENGUELLI, 1940, pp. 48-51, figs. 5a, 5b, 5c, 6e.**TYPE LOCALITY.** Karand (Hungary).**DIAGNOSTIC FEATURES.** Skeleton consisting of a "sphere" meshwork of windows; frequently, about three-quarters of a sphere.**DIMENSIONS.** With spines: maximum 25  $\mu$ ; average, 20  $\mu$ . Spines, 3-5  $\mu$ .

&lt;

FIGURE 3. *Corbisema geometrica* Hanna. Syntype no. 3054 (CAS). Photograph by G D. Hanna. Moreno shale, Fresno County, California. Late Cretaceous. California Academy of Sciences locality 1144. Maximum dimension, 0.086 mm.FIGURE 4. *Corbisema geometrica* Hanna. Syntype no. 3053 (Calif. Acad. Sci.). Photograph by G D. Hanna. Moreno shale, Fresno County, California. Late Cretaceous. California Academy of Sciences locality 1144. Maximum dimension, 0.076 mm.FIGURE 5. *Corbisema geometrica* Hanna. Marca shale, Fresno County, California. Late Cretaceous. Maximum dimension, 0.080 mm.FIGURE 6. *Dictyocha fibula* var. *stapedia* (Haeckel). Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.030 mm.FIGURE 7. *Lyramula furcula* Hanna. Marca shale, Fresno County, California. Late Cretaceous. Maximum dimension, 0.090 mm.FIGURE 8. *Lyramula furcula* Hanna. Marca shale, Fresno County, California. Late Cretaceous. Maximum dimension, 0.096 mm.FIGURE 9. *Lyramula simplex* Hanna. Marca shale, Fresno County, California. Late Cretaceous. Maximum dimension, 0.085 mm.FIGURE 10. *Lyramula simplex* Hanna. Holotype no. 3056 (CAS). Photograph by G D. Hanna. Moreno shale, Fresno County, California. Late Cretaceous. California Academy of Sciences locality 1144. Maximum dimension, 0.093 mm.FIGURE 11. *Vallacerta hortoni* Hanna. Marca shale, Fresno County, California. Late Cretaceous. Maximum dimension, 0.065 mm.FIGURE 12. *Vallacerta hortoni* Hanna. Marca shale, Fresno County, California. Late Cretaceous. Maximum dimension, 0.070 mm.FIGURE 13. *Lyramula furcula* Hanna. Marca shale, Fresno County, California. Late Cretaceous. Maximum dimension, 0.059 mm.FIGURE 14. *Dictyocha fibula* Ehrenberg. Drawn by Tokimi Tsujita. Oamura Bay, Japan. Approximate maximum dimension, 0.060 mm.FIGURE 15. *Dictyocha fibula* Ehrenberg. Atypical form collected after "red-tide" in Oamura Bay, Japan. Note change in shape in basal ring (B. r.), loss of two radial spines (R. sp.) and loss of some supporting spines (S. sp.). Drawn by Tokimi Tsujita. Approximate maximum dimension, 0.065 mm.FIGURE 16. *Dictyocha fibula* Ehrenberg. Atypical form collected after "red-tide" in Oamura Bay, Japan. Drawn by Tokimi Tsujita. Approximate maximum dimension, 0.065 mm.FIGURE 17. *Dictyocha fibula* Ehrenberg. Sisquoc formation (Lompoc area), Santa Barbara County, California. Delmontian, late Miocene. Maximum dimension, 0.060 mm.FIGURE 18. *Dictyocha fibula* Ehrenberg. Diatomite at Sharktooth Hill, Kern County, California. Relizian, middle Miocene. Maximum dimension, 0.085 mm.FIGURE 19. *Vallacerta hortoni* Hanna. Marca shale, Fresno County, California. Late Cretaceous. Maximum dimension, 0.069 mm.

STRATIGRAPHIC RECORD. Middle Neogene (Nagy Kurtos and Szt. Peter, Hungary); upper Neogene (Sendai, Japan); younger Tertiary (Karand, Hungary).

OCCURRENCES IN SAMPLES STUDIED. Diatomite at Sharktooth Hill (less than 1 percent), Valmonte diatomite (7 percent).

#### Genus *Corbisema* Hanna

*Corbisema* HANNA, 1928, p. 261. Type species (by original designation): *Corbisema geometrica* Hanna, 1928.

Range of genus in California to date: Upper Cretaceous-Eocene.

World-wide range of genus: Cretaceous-Miocene.

Distribution of genus: Cosmopolitan.

#### *Corbisema apiculata* (Lemmermann).

(Figures 25, 30, 35.)

*Dictyocha triacantha* Ehrenberg var. *apiculata* LEMMERMAN, 1901, p. 259, pl. 10, figs. 19, 20. SCHULZ, 1928, pp. 247-248, figs. 27, 28. GEMEINHARDT, 1930, p. 41, fig. 30. DEFLANDRE, 1936, p. 34, fig. 49.

*Corbisema apiculata* (Lemmermann). HANNA, 1931, p. 198, pl. D, fig. 2.

TYPE LOCALITY. Jutland and Russia are cited in original publication.

DIAGNOSTIC FEATURES. Skeleton triangular shaped with a short spine radiating from each apex; or without spines. This species differs from *Corbisema triacantha* in that the spines of the latter are relatively longer than those of *Corbisema apiculata*. Frequently, *Corbisema apiculata* has no spines.

DIMENSIONS. With spines: maximum, 60  $\mu$ ; average, 45  $\mu$ . Spines, 1-3  $\mu$ .

STRATIGRAPHIC RECORD. Paleocene (Kusnetsk, Russia): lower Eocene (Jutland, Denmark).

OCCURRENCES IN SAMPLES STUDIED. "Sidney Flat" shale (15 percent), Kellogg shale (34 percent).

#### *Corbisema geometrica* Hanna.

(Figures 3, 4, 5.)

*Corbisema geometrica* HANNA, 1928, p. 261, pl. 41, figs. 1, 2. DEFLANDRE, 1940, p. 446, figs. 3, 4, 6-8. DEFLANDRE, 1950, p. 53, figs. 134, 136-139 [not 135].

*Dictyocha triacantha* Ehrenberg var. *apiculata* forma *lateradiata* SCHULZ, 1928, p. 281, fig. 73.

TYPE LOCALITY. California Academy of Sciences locality 1144. Moreno formation (Upper Cretaceous), Panoche Hills, Fresno County, California, SW $\frac{1}{4}$  NE $\frac{1}{4}$  Sec. 6, T. 15 S., R. 12 E., M.D.B.M.

DIAGNOSTIC FEATURES. Equilateral triangular skeleton divided into three windows by internal bars in plane of triangle; bars bisect sides and meet at a central point or central triangular area.

DIMENSIONS. Maximum, 80  $\mu$ ; average, 70  $\mu$ .

STRATIGRAPHIC RECORD. Upper Cretaceous (Moreno formation in California, United States; "Spongiaires siliceux de la craie de Prusse," Germany).

OCCURRENCES IN SAMPLES STUDIED. Marca shade (12 percent).

**Corbisema** species.

(Figure 67.)

**DIAGNOSTIC FEATURES.** Skeleton triangular shaped; apical window formed at intersection of three internal bars which bisect basal sides. Each apex of triangle has one radiating spine which is approximately one-third the length of one basal side.

**DIMENSIONS.** With spines: 40  $\mu$ . Spines, 5–7  $\mu$ . (Only one specimen was found.)

**OCCURRENCES IN SAMPLES STUDIED.** Buttle diatomite (less than 1 percent).

**Corbisema triacantha** (Ehrenberg).

(Figures 28, 31.)

*Dictyocha triacantha* EHRENBURG, 1844, pl. 10, fig. 19, [not 18]. LEMMERMANN, 1901, p. 258, pl. 10, fig. 18. SCHULZ, 1928, p. 247, fig. 24. GEMEINHARDT, 1930, p. 40, figs. 28a, 28b. ZANON, 1934, p. 29, fig. 8.

*Corbisema triacantha* (Ehrenberg). HANNA, 1931, p. 198, pl. D, fig. 1.

**TYPE LOCALITY.** Not stated in original publication.

**DIAGNOSTIC FEATURES.** Skeleton triangular shaped, with one spine radiating from each of the three apexes; spine length approximately equal to side of triangle; center of triangle divided into three equal areas by three bars meeting at center of skeleton.

**DIMENSIONS.** With spines: maximum, 60  $\mu$ ; average, 50  $\mu$ . Spines, 5–15  $\mu$ .

**STRATIGRAPHIC RECORD.** Paleocene (Bojarkino, Kusnetsk, and Simbirsk, Russia); lower Eocene (Mors and Fuur, Denmark); upper Eocene (Oamaru, New Zealand).

**OCCURRENCES IN SAMPLES STUDIED.** "Sidney Flat" shale (8 percent), Kellogg shale (7 percent).

### Genus *Dictyocha* Ehrenberg

*Dictyocha* EHRENBURG, 1838 [1840], p. 128. Type species (by subsequent designation, FRENGUELLI, p. 69, 1940): *Dictyocha fibula* EHRENBURG, 1838 [1840].

Range of genus in California to date: Eocene-Recent.

World-wide range of genus: Cretaceous-Recent.

Distribution of genus: Cosmopolitan.

**Dictyocha ausonia** Deflandre.

(Figure 38.)

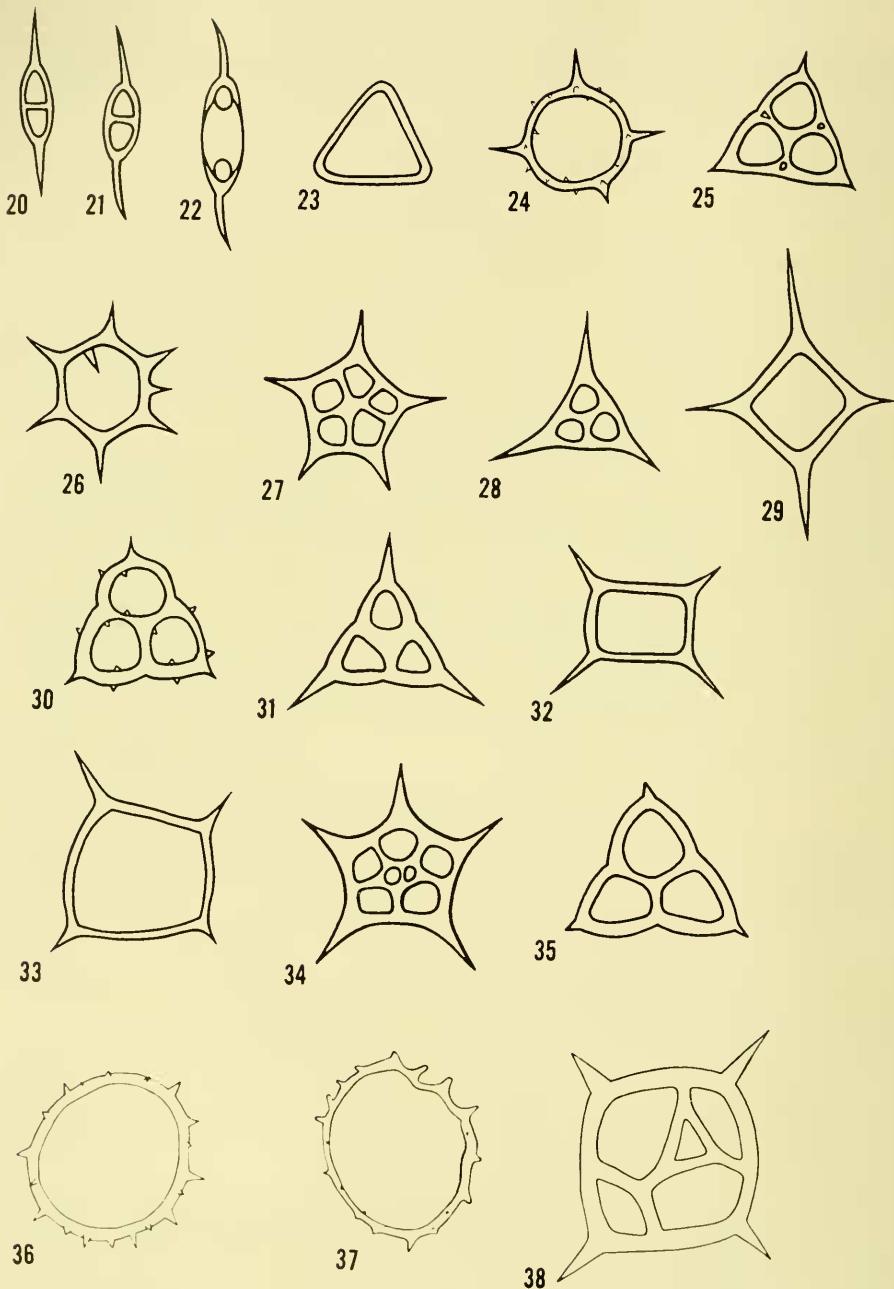
*Dictyocha fibula* EHRENBURG, 1854, pl. 22, fig. 42b [not others]. CARNEVALE, 1908, p. 35, pl. 4, fig. 29.

*Dictyocha ausonia* DEFLANDRE, 1941, p. 101, figs. 8–11, 13. DEFLANDRE, 1950, pp. 67–68, figs. 194–202.

**TYPE LOCALITY.** Not stated in original publication.

**DIAGNOSTIC FEATURES.** Skeleton with elliptical basal ring, with two lateral swellings; basal ring has four radial spines, usually without supporting spines, apical structure slightly elevated.

**DIMENSIONS.** With spines: maximum, 55  $\mu$ ; average, 50  $\mu$ . Spines, 5–10  $\mu$ .



STRATIGRAPHIC RECORD. Middle Neogene (Bergonzano and Marmorito, Italy; Caltanissetta, Sicily).

OCCURRENCES IN SAMPLES STUDIED. Diatomite at Sharktooth Hill (less than 1 percent).

### Dictyocha fibula Ehrenberg.

(Figures 14, 15, 16, 17, 18.)

*Dictyocha fibula* EHRENBURG, 1838 [1840], p. 149. EHRENBURG, 1854, pl. 18, figs. 54a, 54b, 54c; pl. 19, fig. 43; pl. 20, fig. 45; pl. 21, fig. 42. LEMMERMANN, 1901, p. 260, pl. 10, fig. 24. LEMMERMANN, 1903, pp. 27-28, fig. 92. HANNA, 1928a, pl. 9, fig. 10. SCHULZ,

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FIGURE 20. *Naviculopsis biapiculata* (Lemmermann). Kellogg shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.067 mm.

FIGURE 21. *Naviculopsis biapiculata* (Lemmermann). "Sidney Flat" shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.070 mm.

FIGURE 22. *Naviculopsis biapiculata* (Lemmermann). Kellogg shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.081 mm.

FIGURE 23. *Mesocena oamaruensis* Schulz. Kellogg shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.053 mm.

FIGURE 24. *Mesocena polymorpha* var. *quadrangula* (Ehrenberg). Kellogg shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.052 mm.

FIGURE 25. *Corbisema apiculata* (Lemmermann). Kellogg shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.045 mm.

FIGURE 26. *Mesocena polymorpha* var. *biseptenaria* Gemeinhardt. Kellogg shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.061 mm.

FIGURE 27. *Distephanus variabilis* Hanna. "Sidney Flat" shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.058 mm.

FIGURE 28. *Corbisema triacantha* (Ehrenberg). "Sidney Flat" shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.050 mm.

FIGURE 29. *Mesocena occidentalis* Hanna. "Sidney Flat" shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.068 mm.

FIGURE 30. *Corbisema apiculata* (Lemmermann). Kellogg shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.045 mm.

FIGURE 31. *Corbisema triacantha* (Ehrenberg). Kellogg shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.050 mm.

FIGURE 32. *Mesocena occidentalis* Hanna. "Sidney Flat" shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.068 mm.

FIGURE 33. *Mesocena occidentalis* Hanna. Kellogg shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.077 mm.

FIGURE 34. *Distephanus variabilis* Hanna. "Sidney Flat" shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.058 mm.

FIGURE 35. *Corbisema apiculata* (Lemmermann). Kellogg shale, Contra Costa County, California. Late Eocene. Maximum dimension, 0.050 mm.

FIGURE 36. *Paradictyocha polyactis* (Ehrenberg). Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.045 mm.

FIGURE 37. *Paradictyocha polyactis* (Ehrenberg). Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.050 mm.

FIGURE 38. *Dictyocha ausonia* Deflandre. Diatomite at Sharktooth Hill, Kern County, California. Relizian, middle Miocene. Maximum dimension, 0.055 mm.

1928, p. 252. GEMEINHARDT, 1930, p. 47, fig. 39a. ZANON, 1934, p. 30, fig. 11. DEFLANDRE, 1936, p. 29, fig. 31, p. 35, figs. 52, 53. FRENGUELLI, 1935, pl. 1, fig. 13 [not others]; pl. 2, fig. 1 [not others]. FRENGUELLI, 1940, p. 43, fig. 1f.

TYPE LOCALITY. Sicily. (Exact locality not cited.)

DIAGNOSTIC FEATURES. Skeleton elliptical, spines at ends of major and minor axes; raised internal bars oriented approximately at 45° to major and minor axes; two bars meet at the major axis and become one bar.

DIMENSIONS. With spines: maximum, 85  $\mu$ ; average, 60  $\mu$ . Spines, 5–10  $\mu$ .

STRATIGRAPHIC RECORD. Paleocene (Kusnetsk, Russia): lower Eocene (Mors and Fuer, Jutland): lower Neogene (Nankoorii, Nicabar Islands): middle Neogene (Caltanissetta and Licata, Sicily; Nyermegy, Hungary; Monte Gibbio, Italy).

OCCURRENCES IN SAMPLES STUDIED. "Sidney Flat" shale (33 percent), Kellogg shale (16 percent), Buttle diatomite (less than 1 percent), lower part of Sisquoc formation of Purisima Hills (1 percent), lower part of Sisquoc formation of Lompoc area (27 percent), Valmonte diatomite (less than 1 percent), diatomite at Sharktooth Hill (69 percent).

### **Dictyocha fibula Ehrenberg forma rhombica Schulz.**

(Figure 72.)

*Dictyocha fibula Ehrenberg forma rhombica* SCHULZ, 1928, p. 253, fig. 37. GEMEINHARDT, 1930, p. 50, figs. 40a, 40b, 40c. ZANON, 1934, p. 30, figs. 1, 3.

TYPE LOCALITY. Not stated in original publication.

DIAGNOSTIC FEATURES. Skeleton elliptical with raised bridge made of four internal bars; long axis of bridge is minor axis of skeleton (arrangement differs from that of *Dictyocha fibula* which has long axis of bridge as major axis); four radiating spines, one from each end of the two axes.

DIMENSIONS. With spines: maximum, 80  $\mu$ ; average, 65  $\mu$ . Spines, 3–15  $\mu$ .

STRATIGRAPHIC RECORD. Paleocene (Kusnetsk, Russia): lower Eocene (Mors and Fuer, Jutland): upper Neogene (Sendai, Japan).

OCCURRENCES IN SAMPLES STUDIED. Lower part of Sisquoc formation of Lompoc area (1 percent).

### **Dictyocha fibula Ehrenberg var. stapedia Haeckel.**

(Figure 6.)

*Dictyocha stapedia* HAECKEL, 1887, p. 1561, pl. 101, figs. 10–12.

*Dictyocha fibula Ehrenberg stapedia* Haeckel. LEMMERMANN, 1901, p. 261. LEMMERMANN, 1903, p. 29, fig. 96.

*Dictyocha fibula Ehrenberg var. stapedia* Haeckel. SCHULZ, 1928, p. 254, fig. 39. GEMEINHARDT, 1930, p. 53, fig. 42. ZANON, 1934, p. 31, fig. 14.

TYPE LOCALITY. "Tropical and warmer regions of Atlantic, Pacific, and Indian Oceans" are cited in original publication.

DIAGNOSTIC FEATURES. Skeleton elliptical shaped with raised bridge of internal bars; four short spines radiate inward from inner margin of basal ring; apical bridge has one vertical spine.

**DIMENSIONS.** With spines: maximum, 30  $\mu$ ; average, 25  $\mu$ . Spines, 3–8  $\mu$ .

**STRATIGRAPHIC RECORD.** Middle Neogene (Dolje, Yugoslavia; Licata, Sicily; Bremia, Hungary).

**OCCURRENCES IN SAMPLES STUDIED.** Valmonte diatomite (less than 1 percent).

### **Dictyocha staurodon Ehrenberg.**

(Figure 65.)

*Dictyocha staurodon* EHRENBURG, 1844, p. 80. EHRENBURG, 1854, pl. 18, fig. 58. HAECKEL, 1887, p. 1560. LEMMERMANN, 1901, p. 259, pl. 10, figs. 22, 23. LEMMERMANN, 1903, p. 27, fig. 97. SCHULZ, 1928, p. 251, figs. 34a, 34b, 34c, 34d, 34e, 34f. GEMEINHARDT, 1930, p. 46, figs. 38a, 38b, 38c. ZANON, 1934, p. 29, figs. 9, 10.

**TYPE LOCALITY.** Not stated in original publication.

**DIAGNOSTIC FEATURES.** Skeleton quadrangular or rhombic; vertical spine, short or long; raised internal bars divide skeleton into four parallelograms of equal area; four spines in the basal plane extend from the ends of the major and minor axes of the ellipse.

**DIMENSIONS.** With spines: maximum, 50  $\mu$ ; average, 38  $\mu$ . Spines, 5–15  $\mu$ .

**STRATIGRAPHIC RECORD.** Paleocene (Kusnetsk, Russia); lower Eocene (Mors and Fuer, Jutland); upper Eocene-lower Oligocene (Barbados, island north of South America); lower Neogene (Moron, Spain); middle Neogene (Dolje, Yugoslavia; Bremia, Hungary; "Richmond" and "Santa Monica," United States).

**OCCURRENCES IN SAMPLES STUDIED.** Lower part of Sisquoc formation of Lompoc area (less than 1 percent).

### **Genus *Distephanus* Stöhr**

*Distephanus* STÖHR, 1880, p. 121. Emended by HAECKEL, 1887, pp. 1562–1563. Type species *Distephanus rotundus* (*nom. oblit.*) = *Dictyocha speculum* Ehrenberg 1838 [1840] and is monotypic.

**RANGE OF GENUS IN CALIFORNIA TO DATE:** Eocene-Recent.

**WORLD-WIDE RANGE OF GENUS:** Upper Cretaceous-Recent. (Klement, 1963, and Zanon, 1934, report occurrences in the Albian and in the Middle Triassic. Until these records are confirmed the Upper Cretaceous should be considered the first appearance of this genus.)

**DISTRIBUTION OF GENUS.** Cosmopolitan.

The genus *Distephanus* as originally defined by Stöhr is monotypic. It contains only *Distephanus rotundus*, a synonym for *Dictyocha speculum* (Stöhr, 1880, p. 121, pl. 7, figs. 8a, 8b, 9). Nevertheless, in spite of this error, it is convenient to retain the concept and name of *Distephanus* as emended by Haeckel. Since 1887 there has been cosmopolitan, consistent and frequent usage of this genus (in the sense of Haeckel) by: Borgert, 1891; Lemmermann, 1901; Schulz, 1928; Gemeinhardt, 1930; Marshall, 1934; Zanon, 1934; Yanagisawa, 1943; Hanna, 1944; Margalef, 1957; Mandra, 1960; Tsumura, 1963; and many others listed in the bibliographies of the above papers. The name *Distephanus rotundus* has not been used in any major work for more than 50 years and therefore would be considered invalid according to the International Rules of Zoological Nomen-

clature. Dr. G D. Hanna, California Academy of Sciences and I are convinced that the generic name *Distephanus* serves a useful purpose in the study of silico-flagellates and propose that it be considered a *nomen conservatum*.

### ***Distephanus crux* (Ehrenberg).**

(Figures 59, 64, 81.)

*Dictyocha crux* EHRENBURG, 1838 [1840], p. 207. EHRENBURG, 1854, pl. 18, fig. 56; pl. 20, fig. 46; pl. 33, fig. 9.

*Distephanus crux* (Ehrenberg). HAECKEL, 1887, p. 1563. LEMMERMANN, 1901, p. 262, pl. 11, figs. 6, 7. LEMMERMANN, 1903, p. 29, fig. 98. SCHULZ, 1928, pp. 255-256, fig. 44. GEMEINHARDT, 1930, p. 58, fig. 49. ZANON, 1934, p. 32, fig. 16.

TYPE LOCALITY. Sicily. (Exact locality not known.)

DIAGNOSTIC FEATURES. Skeleton basal ring is square or rhombic with four radiating spines, one at each apex; two of these spines are always longer than the other two. From the middle of the sides (which may be sinuous, round, smooth, or rough with or without spines) radiating inward are four thin internal bars which support an apical window.

DIMENSIONS. With spines: maximum, 60  $\mu$ ; average, 49  $\mu$ . Spines, 2-15  $\mu$ .

STRATIGRAPHIC RECORD. Upper Eocene (Oamaru, New Zealand): lower Neogene (Moron, Spain): middle Neogene (Bremia and Szt. Peter, Hungary; Dolje, Yugoslavia; "Santa Monica," United States): upper Neogene (Sendai, Japan).

OCCURRENCES IN SAMPLES STUDIED. Diatomite at Sharktooth Hill (6 percent), Buttle diatomite (1 percent), Valmonte diatomite (2 percent), lower part of Sisquoc formation of Lompoc area (1 percent), lower part of Sisquoc formation of Purisima Hills (2 percent).

### ***Distephanus ornamentosus* (Ehrenberg).**

(Figure 78.)

*Dictyocha ornamentosum* EHRENBURG, 1844, p. 80.

*Distephanus ornamentosus* (Ehrenberg). HANNA, 1928a, pl. 9, fig. 9.

TYPE LOCALITY. Not stated in original publication.

DIAGNOSTIC FEATURES. Skeleton is six-sided ring, with six radiating spines, six-sided apical window supported by six internal bars which bisect basal sides; six small teeth extending up from inside of the basal ring.

DIMENSIONS. With spines: maximum, 50  $\mu$ ; average, 44  $\mu$ . Spines, 5-10  $\mu$ .

STRATIGRAPHIC RECORD. Miocene (Monterey formation in California, United States).

OCCURRENCES IN SAMPLES STUDIED. Monterey formation at type area (85 percent), Buttle diatomite (less than 1 percent).

### ***Distephanus speculum* (Ehrenberg).**

(Figures 61, 74, 76, 79.)

*Dictyocha speculum* EHRENBURG, 1838 [1840], p. 150. EHRENBURG, 1854, pl. 18, fig. 57; pl. 19, fig. 41; pl. 21, fig. 44b; pl. 22, fig. 47. STÖHR, p. 121, pl. 7, fig. 8.

*Dictyocha ornamentosum* EHRENBURG, 1844, p. 80.

*Distephanus speculum* (Ehrenberg). HAECKEL, 1887, pp. 1563, 1565. LEMMERMANN, 1901, p. 263, pl. 11, fig. 11. SCHULZ, 1928, p. 262. GEMEINHARDT, 1930, pp. 61–62, fig. 53. ZANON, 1934, pp. 32–33, figs. 35, 36, 37.

TYPE LOCALITY. Sicily. (Exact locality not known.)

DIAGNOSTIC FEATURES. Skeleton truncated six-sided pyramid composed of two regular hexagonal rings lying in parallel planes and connected by six ascending inter-radial bars; bars projecting from corners of the upper ring bisect sides of lower large ring; six radiating spines projecting from the corners of lower rings.

DIMENSIONS. With spines: maximum, 50  $\mu$ ; average, 45  $\mu$ . Spines, 5–10  $\mu$ .

STRATIGRAPHIC RECORD. Paleocene (Archangelsk, Simbirsk, and Kusnetsk, Russia); upper Eocene (Oamaru, New Zealand); upper Eocene-lower Oligocene (Barbados, island north of South America); lower Neogene (Moron, Spain; Nankoorii, Nicobar Islands); middle Neogene (Licata and Caltanissetta, Sicily; Szakal and Nagy Kurtos, Hungary; Mejillones, Bolivia; "San Pedro," "Santa Monica," and "Nottingham" United States); upper Neogene (Sendai, Japan).

OCCURRENCES IN SAMPLES STUDIED. Diatomite at Sharktooth Hill (7 percent), Buttle diatomite (78 percent), Monterey formation at type area (13 percent), Valmonte diatomite (2 percent), lower part of Sisquoc formation of Lompoc area (62 percent), lower part of Sisquoc formation of Purisima Hills (93 percent), Kellogg shale (6 percent).

### ***Distephanus speculum* (Ehrenberg) var. *brevispinus* Lemmermann.**

(Figure 83.)

*Distephanus speculum* (Ehrenberg) var. *brevispinus* LEMMERMANN, 1901, p. 264, pl. 11, fig. 14.

TYPE LOCALITY. Pacific Ocean and Baltic Sea are cited in original publication.

DIAGNOSTIC FEATURES. Skeleton six-sided with six-sided apical window; short radiating spines from vertices of basal ring; apical window supported by internal bars bisecting basal sides; six short supporting internal spines.

DIMENSIONS. With spines: maximum, 50  $\mu$ ; average, 46  $\mu$ . Spines, 2–3  $\mu$ .

STRATIGRAPHIC RECORD. Miocene (California, United States).

OCCURRENCES IN SAMPLES STUDIED. Diatomite at Sharktooth Hill (less than 1 percent), Buttle diatomite (15 percent), Valmonte diatomite (less than 1 percent), lower part of Sisquoc formation of Lompoc area (3 percent), Monterey formation at type area (less than 1 percent), lower part of Sisquoc formation of Purisima Hills (1 percent).

### ***Distephanus speculum* (Ehrenberg) var. *pentagonus* Lemmermann.**

(Figures 62, 69.)

*Distephanus speculum* (Ehrenberg) var. *pentagonus* LEMMERMANN, 1901, p. 264, pl. 11, fig. 19. SCHULZ, 1928, pp. 261, 263, fig. 57. GEMEINHARDT, 1930, p. 65, fig. 57. ZANON, 1934, p. 34, fig. 39.

TYPE LOCALITY. Not stated in original publication.

DIAGNOSTIC FEATURES. Skeleton pentagonal basal ring with five spines, more or less equal; apical ring pentagonal, with or without spines.

DIMENSIONS. With spines; maximum, 40  $\mu$ ; average, 33  $\mu$ . Spines, 5  $\mu$ .

STRATIGRAPHIC RECORD. Middle Miocene (Cupramontana, Italy); middle Neogene (Bremia, Hungary; Grggenti and Licata, Sicily; "Santa Monica" and "Santa Barbara," United States).

OCCURRENCES IN SAMPLES STUDIED. Buttle diatomite (1 percent).

### **Distephanus variabilis Hanna.**

(Figures 27, 34.)

*Distephanus variabilis* HANNA, 1931, pl. D, fig. 8; pl. E, figs. 4-7.

TYPE LOCALITY. California Academy of Sciences locality 1832. Kreyenhagen shale (upper Eocene at this locality) Antioch, Contra Costa County, California, NE $\frac{1}{4}$  Sec. 2, T. 1 N., R. 1 E., M.D.B.M.

DIAGNOSTIC FEATURES. Skeleton five-sided basal ring; spines radiating from each of the five corners; apical bridge with or without windows.

DIMENSIONS. With spines: maximum, 65  $\mu$ ; average, 58  $\mu$ . Spines, 5-10  $\mu$ .

STRATIGRAPHIC RECORD. Upper Eocene ("Sidney Flat" and Kellogg shales in California, United States). See Hanna (1931).

OCCURRENCES IN SAMPLES STUDIED. "Sidney Flat" shale (12 percent), Kellogg shale (7 percent).

### **Genus Lyramula Hanna**

*Lyramula* HANNA, 1928, p. 262. Type species (by original designation): *Lyramula furcula* Hanna, 1928.

Range of genus in California to date: Upper Cretaceous.

World-wide range of genus: Upper Cretaceous.

Distribution of genus: California, U.S.A.

### **Lyramula furcula Hanna.**

(Figures 7, 8, 13.)

*Lyramula furcula* HANNA, 1928, p. 262, pl. 41, figs. 4, 5. DEFLANDRE, 1936, p. 32, fig. 45. DEFLANDRE, 1940, p. 509, figs. 1-4. DEFLANDRE, 1950, p. 61/82, figs. 163, 165, 167-169.

TYPE LOCALITY. California Academy of Sciences locality 1144. Moreno formation (Upper Cretaceous), Panoche Hills, Fresno County, California, SW $\frac{1}{4}$  NE $\frac{1}{4}$  Sec. 6, T. 15 S., R. 12 E., M.D.B.M.

DIAGNOSTIC FEATURES. Simple Y-shaped hollow bar of silica, three ends sharply pointed; stalk of Y being shortest.

DIMENSIONS. With spines: maximum, 110  $\mu$ ; average, 90  $\mu$ . Spines, 10-20  $\mu$ .

STRATIGRAPHIC RECORD. "Le Senonien de Prusse," Germany. Upper Cretaceous (Moreno formation in Calif.).

OCCURRENCES IN SAMPLES STUDIED. Marca shale (79 percent).

### **Lyramula simplex Hanna.**

(Figures 9, 10.)

*Lyramula simplex* HANNA, 1928, p. 262, pl. 41, fig. 6. DEFLANDRE, 1936, p. 32, fig. 44. DEFLANDRE, 1940, p. 509, figs. 5, 6. DEFLANDRE, 1950, p. 61/82, figs. 164, 166.

TYPE LOCALITY. California Academy of Sciences locality 1144. Moreno formation (Upper Cretaceous), Panoche Hills, Fresno County, California, SW $\frac{1}{4}$

NE $\frac{1}{4}$  Sec. 6, T. 15 S., R. 12 E., M.D.B.M.

DIAGNOSTIC FEATURES. Simple U-shaped bar of hollow silica.

DIMENSIONS. Maximum,  $90\mu$ ; average,  $85\mu$ .

STRATIGRAPHIC RECORD. "Le Senonien de Prusse," Germany. Upper Cretaceous (Moreno formation in California).

OCCURRENCES IN SAMPLES STUDIED. Marca shale (2 percent).

#### Genus **Mesocena** Ehrenberg

*Mesocena* EHRENBURG, 1841 [1843], p. 401. Type species (by subsequent designation, FRENGUELLI, 1940, p. 69): *Mesocena elliptica* EHRENBURG, 1841 [1843].

Range of genus in California to date: Eocene-Miocene.

World-wide range of genus: Eocene-Miocene.

Distribution of genus: Cosmopolitan.

#### **Mesocena crenulata** Ehrenberg.

(Figure 46.)

*Mesocena crenulata* EHRENBURG, 1860, p. 822 [no figs.]. LEMMERMANN, 1901, p. 255 [no figs.].

*Mesocena annulus* HAECKEL, 1887, p. 1555 [no figs.].

TYPE LOCALITY. Not stated in original publication.

DIAGNOSTIC FEATURES. Skeleton ring elliptical, smooth or slightly denticulate on the outer margin, without spines; major axis of ellipse is 1 to  $1\frac{1}{2}$  times as long as the minor axis.

DIMENSIONS. Maximum,  $60\mu$ ; average,  $52\mu$ . Thickness of bar,  $2\mu$ .

STRATIGRAPHIC RECORD. Greece. (Exact locality not known.)

OCCURRENCES IN SAMPLES STUDIED. Valmonte diatomite (1 percent).

#### **Mesocena crenulata** Ehrenberg var. **diodon** Ehrenberg.

(Figures 44, 47, 49, 51, 53, 57.)

*Mesocena diodon* EHRENBURG, 1844, p. 84. EHRENBURG, 1854, pl. 33, fig. 18.

*Mesocena crenulata* Ehrenberg var. *diodon* Ehrenberg. LEMMERMANN, 1901, p. 255, pl. 10, figs. 1, 2. SCHULZ, 1928, p. 236, figs. 1a, 1b. GEMEINHARDT, 1930, p. 27, fig. 10. ZANON, 1934, p. 26, fig. 1.

TYPE LOCALITY. Not stated in original publication.

DIAGNOSTIC FEATURES. Skeleton ring elliptical, usually denticulate, with two spines at the ends of the major axis.

DIMENSIONS. With spines: maximum,  $60\mu$ ; average,  $52\mu$ . Spines,  $2-10\mu$ .

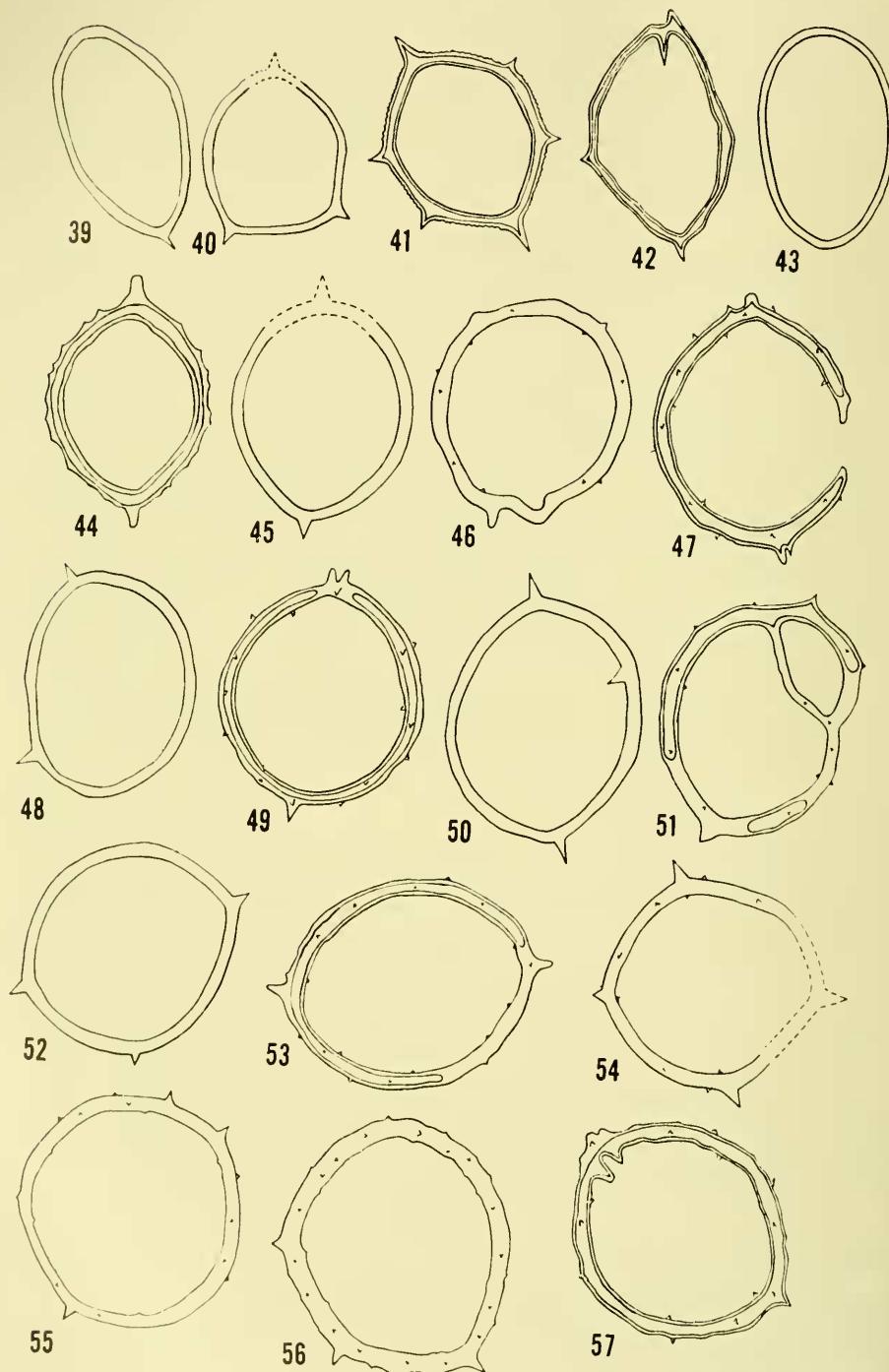
STRATIGRAPHIC RECORD. Upper Eocene-lower Oligocene (Barbados, island north of South America): lower Neogene (Moron, Spain): middle Neogene (Monte Gibbio, Italy; Szt. Peter, Hungary; "Redondo," "Richmond," and "Santa Monica," United States).

OCCURRENCES IN SAMPLES STUDIED. Valmonte diatomite (75 percent), Buttle diatomite (less than 1 percent).

#### **Mesocena crenulata** Ehrenberg var. **elliptica** (Ehrenberg).

(Figure 54.)

*Mesocena elliptica* EHRENBURG, 1844, p. 84. EHRENBURG, 1854, pl. 20, fig. 44.



*Dictyocha elliptica* EHRENCBERG, 1872, p. 44.

*Mesocena crenulata* Ehrenberg var. *elliptica* Ehrenberg. LEMMERMANN, 1901, p. 255 [no fig.]. SCHULZ, 1928, p. 236, fig. 2. GEMEINHARDT, 1930, p. 27, fig. 11. ZANON, 1934, p. 27.

TYPE LOCALITY. Not stated in original publication.

DIAGNOSTIC FEATURES. Skeleton rings elliptical or ovate; one spine projects from each end of the major axis and one from each end of the minor axis of the ellipse.

DIMENSIONS. With spines: maximum, 60  $\mu$ ; average, 54  $\mu$ . Spines, 2–6  $\mu$ .

←

FIGURE 39. *Mesocena polymorpha* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.045 mm.

FIGURE 40. *Mesocena polymorpha* var. *triangula* (Ehrenberg). Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.057 mm.

FIGURE 41. *Mesocena hexagona* Haeckel. Buttle diatomite, Monterey County, California. Delmontian, late Miocene. Maximum dimension, 0.033 mm.

FIGURE 42. *Mesocena polymorpha* var. *triangula* (Ehrenberg). Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.060 mm.

FIGURE 43. *Mesocena polymorpha* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.047 mm.

FIGURE 44. *Mesocena crenulata* var. *diodon* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.052 mm.

FIGURE 45. *Mesocena polymorpha* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.050 mm.

FIGURE 46. *Mesocena crenulata* Ehrenberg. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.052 mm.

FIGURE 47. *Mesocena crenulata* var. *diodon* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.056 mm.

FIGURE 48. *Mesocena polymorpha* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.046 mm.

FIGURE 49. *Mesocena crenulata* var. *diodon* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.054 mm.

FIGURE 50. *Mesocena polymorpha* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.048 mm.

FIGURE 51. *Mesocena crenulata* var. *diodon* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.057 mm.

FIGURE 52. *Mesocena polymorpha* var. *triangula* (Ehrenberg). Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.051 mm.

FIGURE 53. *Mesocena crenulata* var. *diodon* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.053 mm.

FIGURE 54. *Mesocena crenulata* var. *elliptica* (Ehrenberg). Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.054 mm.

FIGURE 55. *Mesocena polymorpha* var. *triangula* (Ehrenberg). Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.049 mm.

FIGURE 56. *Mesocena polymorpha* var. *triangula* (Ehrenberg). Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.058 mm.

FIGURE 57. *Mesocena crenulata* var. *diodon* Lemmermann. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.051 mm.

STRATIGRAPHIC RECORD. Middle Neogene (Caltanissetta, Sicily; "Nottingham," United States); upper Neogene (Zante, Greece).

OCCURRENCES IN SAMPLES STUDIED. Valmonte diatomite (less than 1 percent), Monterey formation at type area (less than 1 percent).

### **Mesocena hexagona Haeckel.**

(Figure 41.)

*Mesocena hexagona* HAECKEL, 1887, p. 1556 [no fig.]. HANNA, 1928a, pl. 9, figs. 6-8.

TYPE LOCALITY. Not stated in original publication.

DIAGNOSTIC FEATURES. Skeleton regular hexagonal with six radial spines on six corners.

DIMENSIONS. With spines: maximum, 35  $\mu$ ; average, 30  $\mu$ . Spines, 2-7  $\mu$ .

STRATIGRAPHIC RECORD. Miocene (Monterey formation in California, United States); middle Neogene (Corfu, exact locality not known).

OCCURRENCES IN SAMPLES STUDIED. Buttle diatomite (less than 1 percent).

### **Mesocena oamaruensis Schulz.**

(Figure 23.)

*Mesocena oamaruensis* SCHULZ, 1928, p. 241, figs. 10a, 10b. GEMEINHARDT, 1930, p. 34, fig. 20.

TYPE LOCALITY. Not stated in original publication.

DIAGNOSTIC FEATURES. Skeleton triangular, no spines.

DIMENSIONS. Maximum, 60  $\mu$ ; average, 53  $\mu$ .

STRATIGRAPHIC RECORD. Upper Eocene (Oamaru, New Zealand).

OCCURRENCES IN SAMPLES STUDIED. Kellogg shale (5 percent).

### **Mesocena occidentalis Hanna.**

(Figures 29, 32, 33.)

*Mesocena occidentalis* HANNA, 1931, pl. E, fig. 1.

TYPE LOCALITY. California Academy of Sciences locality 1832. Kreyenhagen shale (upper Eocene at this locality), Antioch, Contra Costa County, California, NE $\frac{1}{4}$  Sec. 2, T. 1 N., R. 1 E., M.D.B.M.

DIAGNOSTIC FEATURES. Skeleton square, with spines radiating out from each corner; sides straight or slightly convex, spines long or short.

DIMENSIONS. With spines: maximum, 77  $\mu$ ; average, 68  $\mu$ . Spines, 5-15  $\mu$ .

STRATIGRAPHIC RECORD. Upper Eocene ("Sidney Flat" and Kellogg shales in California, United States). See Hanna (1931).

OCCURRENCES IN SAMPLES STUDIED. "Sidney Flat" shale (17 percent), Kellogg shale (1 percent).

### **Mesocena polymorpha Lemmermann.**

(Figures 39, 43, 45, 48, 50.)

*Mesocena polymorpha* LEMMERMANN, 1901, p. 255 [no fig.]. SCHULZ, 1928, p. 237. GEMEINHARDT, 1930, p. 27.

TYPE LOCALITY. Not stated in original publication.

DIAGNOSTIC FEATURES. Skeleton simple, circular to many sided ring.

**DIMENSIONS.** With spines: maximum, 50  $\mu$ ; average, 45  $\mu$ . Spines, usually less than 5  $\mu$ .

**STRATIGRAPHIC RECORD.** Miocene (California, United States).

**OCCURRENCES IN SAMPLES STUDIED.** Valmonte diatomite (less than 1 percent).

**Mesocena polymorpha** Lemmermann var. *biseptenaria* Gemeinhardt.

(Figure 26.)

?*Mesocena polymorpha* Lemmermann var. *biseptenaria* GEMEINHARDT, 1930, p. 31, fig. 16.

**TYPE LOCALITY.** Not stated in original publication.

**DIAGNOSTIC FEATURES.** Skeleton six-sided, with spines radiating from each apex; two additional spines, one directed to center of skeleton, and the other bisecting one side and radiating outward.

**DIMENSIONS.** With spines: maximum, 70  $\mu$ , average, 61  $\mu$ . Spines, 2–10  $\mu$ .

**STRATIGRAPHIC RECORD.** Upper Eocene (Oamaru, New Zealand).

**OCCURRENCES IN SAMPLES STUDIED.** Kellogg shale (3 percent).

**Mesocena polymorpha** Lemmermann var. *quadrangula* Ehrenberg.

(Figure 24.)

?*Mesocena quadrangula* EHRENBURG, 1872, pp. 145, 273.

?*Mesocena polymorpha* Lemmermann var. *quadrangula* Ehrenberg. LEMMERmann, 1901, p. 256, pl. 10, figs. 5–7. LEMMERmann, 1903, p. 26, fig. 89. SCHULZ, 1928, pp. 237–238, figs. 4a, 4b, 4c. GEMEINHARDT, 1930, p. 29, fig. 13. ZANON, 1934, p. 27, fig. 4.

**TYPE LOCALITY.** Not stated in original publication.

**DIAGNOSTIC FEATURES.** Skeletal ring square, with four radial spines on corners; shape varies from square to rhomboid to irregular form; sides covered by small tubercles.

**DIMENSIONS.** With spines: maximum, 60  $\mu$ ; average, 52  $\mu$ . Spines, 3–10  $\mu$ .

**STRATIGRAPHIC RECORD.** Lower Neogene (Nankoorii, Nicabar Islands; Moron, Spain); middle Neogene ("Santa Monica," "Santa Maria," and "Nottingham," United States; Szt. Peter, Hungary); upper Neogene (Kittani, Japan; Zante, Greece).

**OCCURRENCES IN SAMPLES STUDIED.** Kellogg shale (1 percent), "Sidney Flat" shale (1 percent).

**Mesocena polymorpha** Lemmermann var. *triangula* Ehrenberg.

(Figures 40, 42, 52, 55, 56.)

?*Mesocena triangula* EHRENBURG, 1840, p. 208. EHRENBURG, 1854, pl. 22, fig. 41.

?*Dictyocha triangula* EHRENBURG, 1875, p. 46.

?*Lithocircus triangularis* STÖHR, 1880, p. 121, pl. 7, fig. 10.

?*Mesocena polymorpha* Lemmermann var. *triangula* Ehrenberg. LEMMERmann, 1901, p. 255, pl. 10, figs. 3, 4. SCHULZ, 1928, p. 237, figs. 3a, 3b, 3c. GEMEINHARDT, 1930, p. 28, figs. 12a, 12b, 12c. ZANON, 1934, p. 27, figs. 2, 3.

**TYPE LOCALITY.** Not stated in original publication.

**DIAGNOSTIC FEATURES.** Skeletal ring triangular, with small peripheral spines, and three larger spines at the corners; sides more or less convex, with tendency to become round.

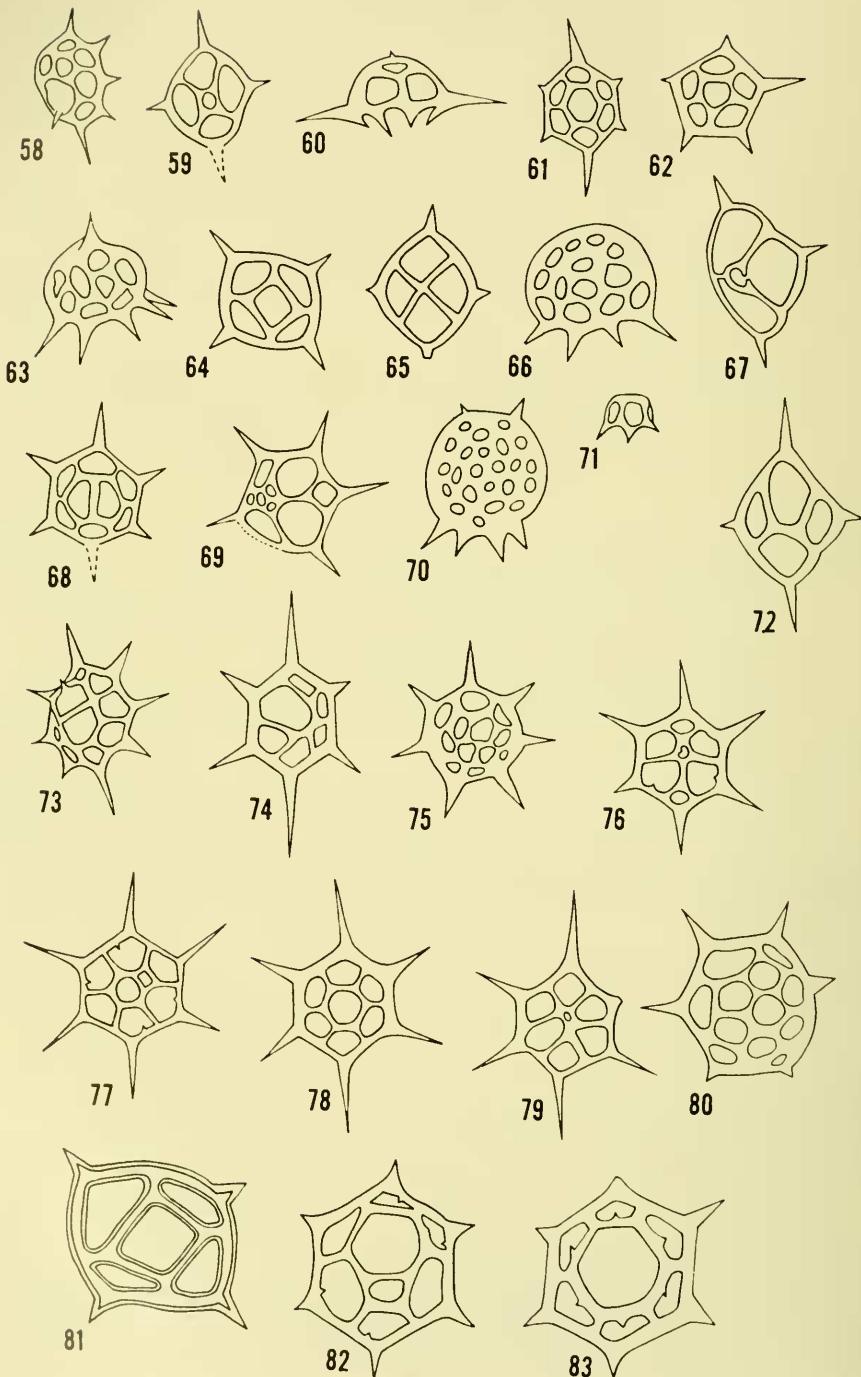


FIGURE 58. *Cannopilus cyrtoides* Haeckel. Diatomite at Sharktooth Hill, Kern County, California. Relizian, middle Miocene. Maximum dimension, 0.032 mm.

FIGURE 59. *Distephanus crux* (Ehrenberg). Sisquoc formation (Purisima Hills), Santa Barbara County, California. Delmontian, late Miocene. Maximum dimension, 0.049 mm.

FIGURE 60. *Cannopilus hemisphericus* (Ehrenberg). Diatomite at Sharktooth Hill, Kern County, California. Relizian, middle Miocene. Maximum dimension, 0.040 mm.

FIGURE 61. *Distephanus speculum* (Ehrenberg). Monterey formation (type area), Monterey County, California. Delmontian, late Miocene. Maximum dimension, 0.045 mm.

FIGURE 62. *Distephanus speculum* var. *pentagonus* Lemmermann. Butte diatomite, Monterey County, California. Delmontian, late Miocene. Maximum dimension, 0.033 mm.

FIGURE 63. *Cannopilus hemisphericus* (Ehrenberg). Diatomite at Sharktooth Hill, Kern County, California. Relizian, middle Miocene. Maximum dimension, 0.050 mm.

FIGURE 64. *Distephanus crux* (Ehrenberg). Sisquoc formation (Purisima Hills), Santa Barbara County. Delmontian, late Miocene. Maximum dimension, 0.060 mm.

FIGURE 65. *Dictyocha staurodon* Ehrenberg. Sisquoc formation (Lompoc area), Santa Barbara County. Delmontian, late Miocene. Maximum dimension, 0.038 mm.

FIGURE 66. *Cannopilus hemisphericus* (Ehrenberg). Diatomite at Sharktooth Hill, Kern County, California. Relizian, middle Miocene. Maximum dimension, 0.047 mm.

FIGURE 67. *Corbisema* species. Butte diatomite, Monterey County, California. Delmontian, late Miocene. Maximum dimension, 0.040 mm.

FIGURE 68. *Cannopilus binoculus* (Ehrenberg). Monterey formation (type area), Monterey County, California. Delmontian, late Miocene. Maximum dimension, 0.048 mm.

FIGURE 69. *Distephanus speculum* var. *pentagonus* Lemmermann. Butte diatomite, Monterey County, California. Delmontian, late Miocene. Maximum dimension, 0.040 mm.

FIGURE 70. *Cannopilus sphericus* Gemeinhardt. Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.025 mm.

FIGURE 71. *Cannopilus hemisphericus* (Ehrenberg). Diatomite at Sharktooth Hill, Kern County, California. Relizian, middle Miocene. Maximum dimension, 0.039 mm.

FIGURE 72. *Dictyocha fibula* var. *rhombica* Schulz. Sisquoc formation (Lompoc area), Santa Barbara County, California. Delmontian, late Miocene. Maximum dimension, 0.065 mm.

FIGURE 73. *Cannopilus binoculus* (Ehrenberg). Sisquoc formation (Lompoc area), Santa Barbara County, California. Delmontian, late Miocene. Maximum dimension, 0.060 mm.

FIGURE 74. *Distephanus speculum* (Ehrenberg). Monterey formation (type area), Monterey County, California. Delmontian, late Miocene. Maximum dimension, 0.050 mm.

FIGURE 75. *Cannopilus cyrtoides* Haeckel. Diatomite at Sharktooth Hill, Kern County, California. Relizian, middle Miocene. Maximum dimension, 0.040 mm.

FIGURE 76. *Distephanus speculum* (Ehrenberg). Butte diatomite, Monterey County, California. Delmontian, late Miocene. Maximum dimension, 0.047 mm.

FIGURE 77. *Cannopilus binoculus* (Ehrenberg). Sisquoc formation (Lompoc area), Santa Barbara County, California. Delmontian, late Miocene. Maximum dimension, 0.054 mm.

FIGURE 78. *Distephanus ornamentos* (Ehrenberg). Monterey formation (type area), Monterey County, California. Delmontian, late Miocene. Maximum dimension, 0.044 mm.

FIGURE 79. *Distephanus speculum* (Ehrenberg). Sisquoc formation (Purisima Hills), Santa Barbara County, California. Delmontian, late Miocene. Maximum dimension, 0.042 mm.

FIGURE 80. *Cannopilus calyptra* Haeckel. Diatomite at Sharktooth Hill, Kern County. Relizian, middle Miocene. Maximum dimension, 0.035 mm.

FIGURE 81. *Distephanus crux* (Ehrenberg). Sisquoc formation (Purisima Hills), Santa Barbara County, California. Delmontian, late Miocene. Maximum dimension, 0.044 mm.

FIGURE 82. *Cannopilus binoculus* (Ehrenberg). Valmonte diatomite, Los Angeles County, California. Mohnian, late Miocene. Maximum dimension, 0.042 mm.

FIGURE 83. *Distephanus speculum* var. *brevispinus* Lemmermann. Butte diatomite, Monterey County, California. Delmontian, late Miocene. Maximum dimension, 0.046 mm.

**DIMENSIONS.** With spines: maximum, 60  $\mu$ ; average, 55  $\mu$ . Spines, 2–5  $\mu$ .

**STRATIGRAPHIC RECORD.** Lower Neogene (Moron, Spain): middle Neogene ("Santa Maria," "Santa Monica," and "Nottingham," United States; Nagy Kurtos, Szakal, and Szt. Peter, Hungary; Caltanissetta and Grotte, Sicily).

**OCCURRENCES IN SAMPLES STUDIED.** Diatomite at Sharktooth Hill (less than 1 percent), Valmonte diatomite (4 percent).

### Genus *Naviculopsis* Frenguelli

*Naviculopsis* FRENGUELLI, 1940, p. 69. Type species (by original designation, FRENGUELLI, 1940): *Naviculopsis biapiculata* (Lemmermann) = *Dictyocha navicula* Ehrenberg var. *biapiculata* LEMMERMAN, 1901.

Range of genus in California to date: Eocene.

World-wide range of genus: Eocene.

Distribution of genus: Cosmopolitan.

#### *Naviculopsis biapiculata* (Lemmermann).

(Figures 20, 21, 22.)

*Dictyocha navicula* Ehrenberg var. *biapiculata* LEMMERMAN, 1901, p. 258, pl. 10, figs. 14, 15. SCHULZ, 1928, p. 244, figs. 18a, 18b, 19. ZANON, 1934, p. 28, fig. 6.

*Naviculopsis biapiculata* (Lemmermann). FRENGUELLI, 1940, p. 60, figs. 11c, 11d.

**TYPE LOCALITY.** Dolje, Fuur, and Kusnetzk are cited in original publication.

**DIAGNOSTIC FEATURES.** Skeleton elliptical ring with one bar across minor axis, and one spine at each end of major axis.

**DIMENSIONS.** With spines: maximum, 80  $\mu$ ; average, 70  $\mu$ . Spines, 5–15  $\mu$ .

**STRATIGRAPHIC RECORD.** Paleocene (Kusnetsk, Russia): lower Eocene (Fuur and Mors, Jutland): upper Eocene (Oamaru, New Zealand): middle Neogene (Dolje, Yugoslavia).

**OCCURRENCES IN SAMPLES STUDIED.** Kellogg shale (19 percent), "Sidney Flat" shale (14 percent).

### Genus *Paradictyocha* Frenguelli

*Paradictyocha* FRENGUELLI, 1940, p. 69. Type species (by original designation, FRENGUELLI, 1940): *Paradictyocha polyactis* (Ehrenberg) = *Dictyocha polyactis* Ehrenberg, 1844.

Range of genus in California to date: Miocene.

World-wide range of genus: Oligocene-Miocene.

Distribution of genus: California, U.S.A.; Japan; Europe.

#### *Paradictyocha polyactis* (Ehrenberg).

(Figures 36, 37.)

*Dictyocha polyactis* EHRENBURG, 1844, p. 80. EHRENBURG, 1854, pl. 20, fig. 50.

*Paradictyocha polyactis* (Ehrenberg). FRENGUELLI, 1940, p. 52, fig. 7g; p. 54, figs. 8a, 8b, 8c, 8d, 8e.

**TYPE LOCALITY.** Moron, Spain.

**DIAGNOSTIC FEATURES.** Skeleton circular or elliptical, approximately 15–25 pronounced bosses each of which is almost as long as the rod diameter of the basal ring.

TABLE 6. *Alphabetical arrangement of California silicoflagellate species.*

CALIFORNIA SILICOFLAGELLATE SPECIES					
UPPER CRET.	UPPER EOCENE	MIOCENE			ALPHABETICAL ARRANGEMENT OF SPECIES
		REL.	MOH.	DEL.	
					<i>Connopilus binoculus</i>
					<i>Connopilus colyptra</i>
					<i>Connopilus cyrtoides</i>
					<i>Connopilus hemisphericus</i>
					<i>Connopilus sphericus</i>
					<i>Corbisema apiculata</i>
					<i>Corbisema geometrica</i>
					<i>Corbisema triacantha</i>
					<i>Dictyocha ausonia</i>
					<i>Dictyocha fibula</i>
					<i>Dictyocha fibula</i> var. <i>rhombica</i>
					<i>Dictyocha fibula</i> var. <i>stapedia</i>
					<i>Dictyocha staurodon</i>
					<i>Distephanus crux</i>
					<i>Distephanus ornamentus</i>
					<i>Distephanus speculum</i>
					<i>Distephanus speculum</i> var. <i>brevispinus</i>
					<i>Distephanus speculum</i> var. <i>pentagonus</i>
					<i>Distephanus variabilis</i>
					<i>Lyramula furcula</i>
					<i>Lyramula simplex</i>
					<i>Mesocena crenulata</i>
					<i>Mesocena crenulata</i> var. <i>diodon</i>
					<i>Mesocena crenulata</i> var. <i>elliptica</i>
					<i>Mesocena hexagona</i>
					<i>Mesocena oomoruensis</i>
					<i>Mesocena occidentalis</i>
					<i>Mesocena polymorpha</i>
					<i>Mesocena polymorpha</i> var. <i>biseptenaria</i>
					<i>Mesocena polymorpha</i> var. <i>quadrangle</i>
					<i>Mesocena polymorpha</i> var. <i>triangulo</i>
					<i>Noviculopsis biapiculata</i>
					<i>Parodictyocha polyactis</i>
					<i>Volvocera hortani</i>

TABLE 7. California silicoflagellate species grouped according to series and stage distribution.

CALIFORNIA SILICOFLAGELLATE SPECIES					
UPPER CRET.	UPPER EOCENE	MIOCENE			GROUPING OF SPECIES ACCORDING TO SERIES AND STAGE DISTRIBUTION
		REL.	MOH.	DEL.	
					<i>Corbisema</i> <i>geometrica</i> <i>Lyramula</i> <i>simplex</i> <i>Lyramula</i> <i>furcula</i> <i>Vallacerta</i> <i>hortoni</i>
					<i>Corbisema</i> <i>apiculata</i> <i>Corbisema</i> <i>triacantha</i> <i>Distephanus</i> <i>variabilis</i> <i>Mesacena</i> <i>oamaruensis</i> <i>Mesacena</i> <i>occidentalis</i> <i>Mesacena</i> <i>polymorpha</i> var. <i>biseptenaria</i> <i>Mesacena</i> <i>polymorpha</i> var. <i>quadrangula</i> <i>Naviculopsis</i> <i>biapiculata</i>
					<i>Dictyocha</i> <i>ousonia</i>
					<i>Dictyocha</i> <i>fibula</i> var. <i>stapedia</i> <i>Mesacena</i> <i>crenulata</i> <i>Mesacena</i> <i>crenulata</i> var. <i>elliptica</i> <i>Mesacena</i> <i>polymorpha</i>
					<i>Dictyocha</i> <i>fibula</i> var. <i>rhombica</i> <i>Dictyocha</i> <i>staurodon</i> <i>Distephanus</i> <i>ornamentus</i> <i>Distephanus</i> <i>speculum</i> var. <i>pentagonus</i> <i>Mesacena</i> <i>hexagona</i>
					<i>Mesacena</i> <i>crenulata</i> var. <i>diodon</i> <i>Mesacena</i> <i>polymorpha</i> var. <i>triangula</i> <i>Cannopilus</i> <i>sphericus</i> <i>Cannopilus</i> <i>cyrtoides</i> <i>Cannopilus</i> <i>hemisphericus</i>
					<i>Cannopilus</i> <i>binoculus</i> <i>Distephanus</i> <i>crux</i> <i>Distephanus</i> <i>speculum</i> var. <i>brevispinus</i> <i>Paradictyocha</i> <i>polyactis</i>
					<i>Dictyocha</i> <i>fibula</i> <i>Distephanus</i> <i>speculum</i> <i>Cannopilus</i> <i>calyptra</i>

**DIMENSIONS.** Maximum, 50  $\mu$ ; average, 45  $\mu$ . Bosses, 1–2  $\mu$ .

**STRATIGRAPHIC RECORD.** Lower Neogene (Moron, Spain).

**OCCURRENCES IN SAMPLES STUDIED.** Buttle diatomite (less than 1 percent), Valmonte diatomite (2 percent), lower part of Sisquoc formation of Lompoc area (2 percent), lower part of Sisquoc formation of Purisima Hills (less than 1 percent).

#### Genus *Vallacerta* Hanna

*Vallacerta* HANNA, 1928, p. 262. Type species (by original designation): *Vallacerta hortoni* Hanna, 1928.

Range of genus in California to date: Upper Cretaceous.

World-wide range of genus: Upper Cretaceous.

Distribution of genus: California, U.S.A.

#### *Vallacerta hortoni* Hanna.

(Figures 11, 12, 19.)

*Vallacerta hortoni* HANNA, 1928, p. 262, pl. 41, figs. 7–11. DEFLANDRE, 1940, p. 446, figs. 1–5; p. 598, fig. 1. DEFLANDRE, 1950, p. 57, figs. 144, 146, 147.

*Dictyocha sidera* SCHULZ, 1928, p. 284, figs. 81a, 81b.

**TYPE LOCALITY.** California Academy of Sciences locality 1144. Moreno formation (Upper Cretaceous), Panoche Hills, Fresno County, California, SW $\frac{1}{4}$  NE $\frac{1}{4}$  Sec. 6, T. 15 S., R. 12 E., M.D.B.M.

**DIAGNOSTIC FEATURES.** Pentagonal disk with radiating spines of equal length at each corner.

**DIMENSIONS.** With spines: maximum, 70  $\mu$ ; average, 65  $\mu$ . Spines, 8–18  $\mu$ .

**STRATIGRAPHIC RECORD.** Upper Cretaceous (Moreno formation in California, United States; "Spongiaires siliceux de la craie de Prusse," Germany).

**OCCURRENCES IN SAMPLES STUDIED.** Marca shale (6 percent).

#### GAZETTEER

This section lists the geographic names used in the text and records for each a map on which the locality can be found. Some areas could not be located on maps.

Quotation marks are used here to indicate that a locality has not been accurately described by prior workers.

The entries record the town (or area), country, latitude, longitude, the atlas in which the name was located, the number of the map, coordinates, and scale.

A space saving procedure has been adopted for atlases which are cited frequently; the names are abridged in the following manner: (1) Atlante = Touring Club italiano Atlante Internazionale, 1951, 231 p., 167 leaves of maps, Milan; (2) Goldmann = Goldmann's Grosser Weltatlas, 1955, 323 p., illus., Munchen, Goldmann; (3) Goode's = Goode's School Atlas, 1948, 286 p., 173 maps, New York, Rand McNally; (4) Stieler's = Stieler's Atlas of Modern Geography, 1925, 316 p., 254 maps, Gotha, Justus Perthes; (5) Times = The Times Atlas

of the World, v. 3, 1955, v. 4, 1956, v. 5, 1957, 49–120 maps, London, The Times Publishing Company; and (6) Club Italiano = *Carta d'Italia del Touring Club Italiano*, 1920, 62 sheets and index, Milan, Published by Touring Club Italiano.

ABASHIRI, HOKKAIDO, JAPAN; lat. 44°00' N., long. 144°15' E.

Map: Atlante, 97–98, D 53, scale 1:10,000,000.

AEGINA ISLAND, SARONIC GULF OF AEGEAN SEA; lat. 37°46' N., long. 23°26' E.

Map: Atlante, 75–76, U 27, scale 1:3,000,000.

ARKANGELSK, RUSSIA. Arkangelsk is not listed in any major atlas. There are, however, 17 entries for Arkhangelsk in Atlante. It is not possible to determine which is the fossil locality of Zanon.

BARBADOS ISLAND, BRITISH WEST INDIES; lat. 13°21' N., long. 59°12' W.

Map: Goldmann, 193, F 18, scale 1:5,000,000.

BERGONZANO, ITALY. Not located. Near Reggio Emilia (lat. 44°42' N., long. 10°38' E.).

BOJARKINO, RUSSIA. Not located.

BOSPORUS (STRAIT), TURKEY; lat. 41°10' N., long. 29°10' E.

Map: Times, v. 4, 83, K 3, scale 1:2,500,000.

BRADLEY, CALIFORNIA, UNITED STATES; lat. 35°54' N., long. 120°48' W.

Map: Times, v. 5, 111, D 6, scale 1:2,500,000.

BREMIA, HUNGARY. Not located.

CALTANISSETTA, SICILY. There is a city and a province of the same name. The locality description by Zanon is not definite. The data given are for the city; lat. 37°29' N., long. 14°04' E.

Map: Times, v. 4, 81, H 9, scale 1:1,000,000.

CASATICO, ITALY. Not located.

CASTELTERMINI, AGRIGENTO PROVINCE, SICILY; lat. 37°33' N., long. 13°38' E.

Map: Times, v. 4, 81, G 8, scale 1:1,000,000.

CATANZARO, ITALY. There is a city and a province of the same name. The locality description by Zanon is not definite. The data given are for the city; lat. 38°54' N., long. 16°36' E.

Map: Times, v. 4, 81, N 6, scale 1:1,000,000.

CLYDE SEA, OFF COAST OF SCOTLAND; lat. 55°30' N., long. 5°00' W.

Map: Goode's, 116, scale 1:4,000,000.

COESFELD, GERMANY; lat. 51°57' N., long. 7°20' E.

Map: Times, v. 3, 63, F 9, scale 1:1,000,000.

CONDRO, ITALY. Not located.

CORFU, CITY ON CORFU ISLAND (OFF COAST OF GREECE). The locality description by Zanon is not definite. The data given are for the city; lat. 39°36' N., long. 19°55' E.

Map: Times, v. 4, 83, D 5, scale 1:2,500,000.

CORMACKS, OAMARU, NEW ZEALAND; lat. 45°07' S., long. 171°02' E.

Map: Goode's, 171, scale 1:4,000,000.

CROTONE, CATANZARO PROVINCE, ITALY; lat. 39°05' N., long. 17°08' E.

Map: Times, v. 4, 81, O 5, scale 1:1,000,000.

CUPRAMONTANA, ANCONA PROVINCE, ITALY; lat. 43°27' N., long. 13°07' E.

Map: Times, v. 4, 80, H 2, scale 1:1,000,000.

DEL MONTE, CALIFORNIA, UNITED STATES; lat. 36°35' N., long. 121°50' W.

Map: Seaside, Monterey County, California; sheet 1657, 111 SE., A.M.S. series V895, Type C-AMS 1; Corps of Engineers, U. S. Army, 1948, scale 1:24,000.

DOLJE, YUGOSLAVIA. Not located.

EGINA. (See Aegina.)

FORMIGNANO, ITALY; lat. 44°04' N., long. 12°05' E.

Map: Club Italiano, Foglio 19 Ravenna, D 5, scale 1:250,000.

FUUR, ISLAND IN LIM FJORD, DENMARK; lat. 57°49' N., long. 9°01' E.

Map: Times, v. 3, 53, C 3, scale 1:1,000,000.

GABBRO, ITALY; lat. 43°28' N., long. 10°28' E.

Map: Club Italiano, Foglio 21 Livorno, B 6, scale 1:250,000.

GIRGENTI, SICILY. There is a city and province of the same name. The locality description by Zanon is not definite. The data given are for the city; lat. 37°18' N., long. 13°35' E.

Map: Times, v. 4, 81, G 9, scale 1:1,000,000.

GREIFSWALDER OIE, BALTIC ISLET, GERMANY; lat. 54°15' N., long. 13°55' E.

Map: Times, v. 3, 63, T 4, scale 1:1,000,000.

GROTTE, AGRIGENTO PROVINCE, SICILY; lat. 37°29' N., long. 14°04' E.

Map: Times, v. 4, 81, G 9, scale 1:1,000,000.

JUTLAND, PENINSULA, DENMARK; lat. 56°00' N., long. 9°00' E.

Map: Times, v. 3, 53, C 4, scale 1:1,000,000.

KARAND, HUNGARY. Not located.

KIEL BAY, GERMANY; lat. 54°30' N., long. 10°30' E.

Map: Times, v. 3, 63, M 4, scale 1:1,000,000.

KII STRAITS, JAPAN; lat. 34°00' N., long. 134°48' E.

Map: Goode's, 159, scale 1:4,000,000.

KITTANAI, JAPAN. Not located.

KOESFELD. (See Coesfeld.)

KUZNETSK, RUSSIA; lat. 53°06' N., long. 46°35' E.

Map: Atlante, 69-70, Q 44, scale 1:3,000,000.

LICATA, AGRIGENTO PROVINCE, SICILY; lat. 44°15' N., long. 10°02' E.

Map: Times, v. 4, 81, G 9, scale 1:1,000,000.

LOMPOC, CALIFORNIA, UNITED STATES; lat. 34°38' N., long. 120°30' W.

Map: Goode's 74, scale 1:4,000,000.

MARMORITO, ITALY; lat. 45°05' N., long. 8°01' E.

Map: Club Italiano, Foglio 9 Torino, D 4, scale 1:250,000.

"MARYLAND," UNITED STATES. The literature does not specify a locality. [It is probable that the Calvert formation, Calvert County, Maryland is the locality of Zanon.]

MARZULLO SORTINO, SICILY. Not located. The following data refer to Sortino near Siracusa, Sicily; lat. 37°10' N., long. 15°02' E.

Map: Times, v. 4, 81 K 9, scale 1:1,000,000.

MEJILLONES OR MEJILLONES DEL SUR, ANTOFAGASTA PROVINCE, CHILE; lat. 23°01' S., long. 70°30' W.

Map: Goode's, 104, scale 1:16,000,000.

MESSINA, SICILY. There is a city and province of the same name. The locality description by Zanon is not definite. The data given are for the city; lat. 38°11' N., long. 15°33' E.

Map: Times, v. 4, 81, L 7, scale 1:1,000,000.

MONACO, PRINCIPALITY; lat. 43°45' N., long. 7°20' E.

Map: Times, v. 4, 67, K 9, scale 1:2,500,000.

MONDAINO, ITALY; lat. 43°53' N., long. 13°15' E.

Map: Club Italiano, Foglio 20 Pesaro, E 2, scale 1:250,000.

MONTAIADE, ITALY. Not located. Since Zanon reports that Montaiae is near Pergola, the following data refer to Pergola; lat. 43°36' N., long. 12°50' E.

Map: Club Italiano, Foglio 24 Macerata, A 3, scale 1:250,000.

MONTE BUSSETTO, ITALY; lat. 43°08' N., long. 13°20' E.

Map: Club Italiano, Foglio 24 Marcerato, D 2-3, scale 1:250,000.

MONTE GEMMANO, FORLI, ITALY. Not located.

MONTE GIBBIO, ITALY; lat. 43°31' N., long. 10°46' E.

Map: Club Italiano, Foglio 18, A 2, scale 1:250,000.

MONTEDISSITO, FORLI, ITALY. Not located.

MONTEFABBRI, ITALY; lat. 43°48' N., long. 13°16' E.

Map: Club Italiano, Foglio 19 Ravenna, D 5, scale 1:250,000.

MONTEFIORE, ITALY. There are 3 entries for Montefiore in Club Italiano. It is not possible to determine which is the fossil locality of Zanon.

MONTEREY, CALIFORNIA, UNITED STATES; lat. 36°35' N., long. 121°55' W.

Map: Times, v. 5, 111, C 5, scale 1:2,500,000.

MONTEVECCIO, ITALY; lat. 44°03' N., long. 12°30' E.

Map: Club Italiano, Foglio 19 Ravenna, D 5, scale 1:250,000.

MOORS. (See Mors.)

MORON, SPAIN; lat. 37°07' N., long. 5°26' W.

Map: Atlante, 41-42, J 4, scale 1:1,500,000.

MORS, ISLAND IN LIM FJORD, DENMARK; lat. 57°48' N., long. 8°40' E.

Map: Times, v. 3, 53, B 3, scale 1:1,000,000.

MOUNT DIABLO, CALIFORNIA, UNITED STATES; lat. 37°45' N., long. 122°50' W.

Map: Times, v. 5, 111, C 4, scale 1:2,500,000.

NAGY KURTOS (SOMETIMES SPELLED NAGY CURTOS), HUNGARY; lat. 46°02' N., long. 19°47' E.  
Map: Stieler, 47, G 5, scale 1:925,000.

NANKOORI, ONE OF THE NICOBAR ISLANDS IN INDIAN OCEAN; lat. 7°45' N., long. 93°30' E.  
Map: Stieler, 71, B 6, scale 1:7,500,000.

NEMURO STRAITS, JAPAN; lat. 44°15' N., long. 145°30' N.

Map: Goode's, 158, scale 1:4,000,000.

NYERMEGY, HUNGARY. Not located.

OAMARU, NEW ZEALAND; lat. 45°07' S., long. 171°02' E.

Map: Goode's, 171, scale 1:4,000,000.

OSAKA BAY, JAPAN; lat. 34°30' N., long. 135°15' E.

Map: Goode's, 159, scale 1:4,000,000.

ORAN, ALGERIA. There are two Orans in Algeria. It is not possible to determine which is the fossil locality of Zanon.

PANOCHIE HILLS (HANNA'S MORENO SHALE LOCALITY), FRESNO COUNTY, CALIFORNIA, UNITED STATES. California Acad. Sci. Loc. 1144, SW $\frac{1}{4}$ NE $\frac{1}{4}$ , sec. 6, T. 15 S., R. 12 E., M.D.B.M.; lat. 36°40' N., long. 120°45' W.

Map: Atlante, 140-141, K 13, scale 1:3,000,000.

PASSAMAQUODDY BAY, MAINE-CANADA; lat. 45°05' N., long. 66°58' W.

Map: Goode's, 86, scale 1:4,000,000.

PLYMOUTH SOUND, GREAT BRITAIN; lat. 50°25' N., long. 4°05' W.

Map: Goode's, 116, scale 1:4,000,000.

"POPLEIA, NORTH AMERICA." Not located.

PURISIMA HILLS, CALIFORNIA, UNITED STATES; lat. 34°38' N., long. 120°30' W.

Map: California Div. Mines Bull. 150, Plates 1, 3.

"REDONDO, NORTH AMERICA." REDONDO, [CALIFORNIA]; lat. 33°48' N., long. 118°25' W.

Map: Goode's, 74, scale 1:4,000,000.

"RICHMOND, NORTH AMERICA." It is not possible to determine which "Richmond" is the fossil locality of Zanon.

SAN CATALDO, SICILY; lat. 37°29' N., long. 14°00' E.

Map: Times, v. 4, 81, G 9, scale 1:1,000,000.

- S. ANGELO DE SENIGALLIA, ANCONA PROVINCE, ITALY; lat. 43°43' N., long. 13°13' E.  
Map: Times, v. 4, 79, 0-7, scale 1:1,000,000.
- SAN JOAQUIN VALLEY, CALIFORNIA, UNITED STATES; lat. 37°30' N., long. 121°10' W.  
Map: Goode's, 74, scale 1:4,000,000.
- "SAN PEDRO, NORTH AMERICA." It is not possible to determine which "San Pedro" is the fossil locality of Zanon. [The literature on diatoms indicates that it may be San Pedro, California.]
- SAN RUFFILLO, ITALY; lat. 46°30' N., long. 11°15' E.  
Map: Atlante, 24, 25-26, T. 65, scale 1:1,250,000.
- "SANTA BARBARA, NORTH AMERICA." SANTA BARBARA, [CALIFORNIA]; lat. 34°25' N., long. 119°41' W.  
Map: Goode's, 74, scale 1:4,000,000.
- "SANTA MARIA, NORTH AMERICA." SANTA MARIA, [CALIFORNIA]; lat. 34°58' N., long. 120°29' W.  
Map: Goode's, 74, scale 1:4,000,000.
- "SANTA MONICA, NORTH AMERICA." SANTA MONICA, [CALIFORNIA]; lat. 34°01' N., long. 118°28' W.  
Map: Goode's, 74, scale 1:4,000,000.
- SENDAI, HONSHU, JAPAN; lat. 38°17' N., long. 140°55' E.  
Map: Goode's, 158, scale 1:10,000,000.
- SERRALUNGA DI CREA, ITALY; lat. 45°10' N., long. 8°18' E.  
Map: Goldmann, 84, 15, scale 1:1,000,000.
- SIMBIRSK, RUSSIA; lat. 54°19' N., long. 48°23' E.  
Map: Atlante, 69-70, O 47, scale 1:3,000,000.
- SOLFATARA, ITALY; lat. 43°48' N., long. 13°08' E.  
Map: Club Italiano, Foglio 20 Pesaro, F 1, scale 1:250,000.
- SPADAFORA, MESSINA PROVINCE, SICILY; lat. 38°13' N., long. 15°23' E.  
Map: Times, v. 4, 81, K 7, scale 1:1,000,000.
- SZAKAL, NEOGRAD PROVINCE, HUNGARY. Not located.
- SZT. PETER, NEOGRAD PROVINCE, HUNGARY. Not located.
- ZANTE, CITY ON ZANTE ISLAND (OFF COAST OF GREECE). The locality description by Zanon is not definite. The following data are for the city; lat. 37°47' N., long. 20°53' E.  
Map: Stieler, 53, B 5, scale 1:1,500,000.
- ZILLY, GERMANY; lat. 51°56' N., long. 10°49' E.  
Map: Goldmann, 61, C-11, scale 1:1,000,000.

## REGISTER OF LOCALITIES

MORENO FORMATION (*Maastrichtian, Upper Cretaceous*)  
L.S.J.U. Loc. M-619\*

CANYON NAME. Escarpado Canyon.

NAME OF UNIT SAMPLED. Diatomite at top 20 feet of 300-foot thick Marca shale member.

*Collectors.* Max B. Payne and Y. T. Mandra, 1957.

*Location.* On ridge immediately north of Escarpado Canyon, 250 feet south and 1700 feet west of NE corner of Sec. 7, T. 15 S., R. 12 E., M.D.B.M., Fresno County, California (120°42' W. and 36°38' N.).

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\* Leland Stanford Junior University (Stanford, California) Micropaleontology Locality M-.

*Map used.* Aerial photograph by Continental Air Map Company, Job #82, Print 12-4, scale 1:18000 (no date).

*Stratigraphic position.* The one sample used came from a horizon 20 feet below the lower Dos Palos shale (of Danian Age).

KELLOGG SHALE (*late Eocene*)

L.S.J.U. Loc. M-611

AREA NAME. Kellogg Creek at Byron Hot Springs Road.

NAME OF UNIT SAMPLED. "Mudstone" from 90-foot exposed section of Kellogg shale at type locality.

Collector. Y. T. Mandra, 1948.

Location. Road cut 2000 feet N. 80° E. of bench mark 165 in NW $\frac{1}{4}$  Sec. 8, T. 1 S., R. 3 E., M.D.B.M., 2.8 miles west of Byron, Contra Costa County, California (121°40'10" W. and 37°51'45" N.).

*Map used.* Byron Quadrangle, California; 15 Minute Series (topographic), Corps of Engineers, U. S. Army, 1937; scale 1:62500.

*Stratigraphic position.* The lowest of the 10 samples came from a horizon approximately 33 feet above a cartographic unit containing a "Domengine Stage" fauna, and 2000 feet below the "Sidney Flat" shale (Laiming's A-1 "Zone" of late Eocene age).

"SIDNEY FLAT" SHALE (*late Eocene*)

L.S.J.U. Loc. M-610

AREA NAME. "Quarry" locality of "Sidney Flat" shale.

NAME OF UNIT SAMPLED. Diatomaceous "mudstone" from 88-foot exposed section of middle (unnamed) 150-foot thick lithologic unit of "Sidney Flat" shale (Markley formation).

Collector. Y. T. Mandra, 1948.

Location. "Quarry" in the NE $\frac{1}{4}$  Sec. 2, T. 1 N., R. 1 E., M.D.B.M., Contra Costa County, California (121°49'49" W. and 37°57'48" N.).

*Map used.* Mount Diablo Quadrangle, California; 15 Minute Series (topographic), Corps of Engineers, U. S. Army, rev., 1937; scale 1:62500.

*Stratigraphic position.* The lowest of the 12 samples is from a horizon approximately 500 feet below the Kirker sandstone (Refugian Stage), and 2000 feet above the Kellogg shale (Laiming's A-2 "Zone" of late Eocene age).

DIATOMITE AT SHARKTOOTH HILL (*Upper Relizian, Miocene*)

L.S.J.U. Loc. M-620

AREA NAME. Sharktooth Hill.

NAME OF UNIT SAMPLED. The diatomite at Sharktooth Hill is a 20-foot thick cartographic unit of the Round Mountain silt (Teblor).

Collector. Y. T. Mandra, 1950; recollected in 1957 by J. Zimmerman, C. C. Church, P. Patterson, and Y. T. Mandra.

*Location.* On west side of north-south stream cut, at elevation of 650 feet; 3870 feet south and 3930 feet west of the NE corner of Sec. 25, T. 28 S., R. 28 E., M.D.B.M., Kern County, California ( $118^{\circ}55'00''$  W. and  $35^{\circ}27'36''$  N.).

*Map used.* Oil center Quadrangle, California; 15 Minute Series (topographic), U. S. Geological Survey, 1954; scale 1:24000.

*Stratigraphic position.* Horizon A is the lowest exposure of the diatomite. Horizon B, the highest exposure, is 100 feet below the Luisian "Bone Beds."

VALMONTE DIATOMITE (*Upper Mohnian, Miocene*)

L.S.J.U. Loc. M-621

AREA NAME. Peck Park (Palos Verdes).

NAME OF UNIT SAMPLED. Valmonte diatomite (750 feet thick).

Collector. Y. T. Mandra, 1950.

*Location.* In ravine near cliff at north edge of Peck Park; 400 feet east and 3350 feet south of the intersection of  $118^{\circ}18'$  W. and  $33^{\circ}46'$  N.; 4 miles north of Point Fermin, in city of San Pedro, Los Angeles County, California.

*Map used.* Plate 1, U. S. Geol. Survey Prof. Paper 207, 1946; scale 1:24000.

*Stratigraphic position.* Horizon A is 200 feet below the top of Valmonte diatomite. Horizon B is 50 feet above A.

SISQUOC FORMATION (*Delmontian, Mio-Pliocene*)

L.S.J.U. Loc. M-622

AREA NAME. Lompoc.

NAME OF UNIT SAMPLED. Diatomite of lower Sisquoc formation. The Sisquoc formation at this locality is 3000 feet thick.

Collector. Y. T. Mandra, 1957.

*Location.* On San Pasqual Road  $1\frac{1}{4}$  miles south of Route 150 ( $120^{\circ}30'$  W. and  $34^{\circ}38'3''$  N.).

*Map used.* Plates 1, 3, California Div. Mines, Bull. 150, 1950; scale 1:62500.

*Stratigraphic position.* Horizon A is 350 feet above Monterey-Sisquoc contact. Horizon B is 50 feet above A.

SISQUOC FORMATION (*Delmontian, Mio-Pliocene*)

L.S.J.U. Loc. M-623

AREA NAME. Western Purisima Hills along Harris-Lompoc Road.

NAME OF UNIT SAMPLED. Diatomaceous "mudstone" in lower part of Sisquoc formation. The Sisquoc formation at this locality is 3000 feet thick.

Collector. Y. T. Mandra, 1957.

*Location.* On road cuts of Harris-Lompoc Road. Horizon A is 7260 feet west and 22,770 feet north of the intersection of  $120^{\circ}30'$  W. and  $34^{\circ}40'$  N. Horizon B is 7260 feet west and 23,760 feet north of the same intersection.

*Map used.* Plates 1, 3, California Div. Mines, Bull. 150, 1950; scale 1:62500.

*Stratigraphic position.* Horizon A is 300 feet above Monterey-Sisquoc contact. Horizon B is 300 feet above A.

BUTTLE DIATOMITE (*Delmontian, Mio-Pliocene*)  
L.S.J.U. Loc. M-624

CANYON NAME. Buttle Canyon.

NAME OF UNIT SAMPLED. Buttle diatomite member of Monterey formation. The diatomite is 500 feet thick at this locality.

Collector. Y. T. Mandra, 1950 and 1957.

Location. Buttle Canyon in NE $\frac{1}{4}$  Sec. 15, T. 24 S., R. 10 E., M.D.B.M., Monterey County, California (120°52'10" W. and 35°51'52" N.).

Map used. Bradley Quadrangle, California; 7.5 Minute Series (topographic), Corps of Engineers, U. S. Army, 1949; scale 1:24000.

*Stratigraphic position.* Horizon A is 300 feet below the top of Buttle diatomite. Horizon B is 250 feet above A.

MONTEREY FORMATION (*Delmontian, Mio-Pliocene*)  
L.S.J.U. Loc. M-335

AREA NAME. Quarry locality of Galliher (1930, p. 22).

NAME OF UNIT. Upper Nonion fauna locality of type Monterey. The Monterey formation is 3000 feet thick at this locality.

Collector. Y. T. Mandra, 1950 and 1957.

Location. Quarry located on ESE side of 420 foot hill, 2000 feet west and 4000 feet south of the intersection of 121°50'00" W. and 36°35'00" N.

Map used. Seaside, Monterey County, California; Sheet 1657, 111 SE; A.M.S. Series V895, Type C—AMS 1; Corps of Engineers, U. S. Army, 1948, scale 1:24000.

*Stratigraphic position.* Horizon A is 600 feet below the top of Monterey formation. Horizon B is 55 feet higher than A.

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